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THE POLARIMETER AND ITS PRACTICAL APPLICATIONS.*

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I. INTRODUCTORY.

INSTRUMENTS used for the measurement of polarized light are variously called *polariscopes, polarimeters,* and *elliptic analyzers.* The first two designations are common when they measure the azimuth of a rectilinear vibration, and the last when they determine the ratio of the axes—the "ellipticity"—of an elliptic vibration. In the present article, the designation *general polarimeter* is applied to those instruments which furnish a complete specification of the polarized light measured, namely, both azimuth and ratio of axes. Where it is desirable to distinguish between them, they are designated as *azimuth polarimeters, elliptic polarimeters* or *general polarimeters,* as the case may be. By so doing, it is hoped to stress with benefit the unity of principle of the different types. As to *practical application* this is meant to include the purely scientific, as well as the industrial applications. The sugar chemist employs an azimuth polarimeter for grading factory products, a practical application which is also industrial. The petrologist may use a polarimeter to identify crystals as a purely scientific application, nevertheless, the application is practical, although it may not be industrial.

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II. FUNDAMENTAL FACTS AND RELATIONS.

1. *Vibration of Light.*—For purposes of analysis, light is considered to be a homogeneous wave-train which may be described as subjecting a vibrant electrical particle of the medium traversed, to a pendular vibration in the tangent plane to the wave-front. This vibration is constant in frequency with both time and azimuth (direction in the tangent plane), and constant in amplitude with time, but in general variable with azimuth. Dependent upon the facts to be explained, this wave-train is assumed to be made up either of two mutually perpendicular rectilinear vibrations having the same frequency but in general differing in amplitude and phase; or of two opposite circularly vibrating trains having the same frequency but also differing, in general, in amplitude and phase. Both of these concepts require the vibrant particle to travel in a definite elliptical path having a definite azimuth and definite frequency. This picture seems, at first thought, far removed from a real description of light waves. Light reaching any point in space from a source homogeneous as to frequency must be a composite of myriads of elementary elliptically vibrating wavelets, each being the result of an electron of a given atom recovering from a shock received through a chance collision, we will say, with another electron, and each ceasing to radiate after the supply of energy received in that shock is spent. We should expect, therefore, the ellipticities of the elementary vibrations to be distributed by pure chance between a circle traced in one direction and a circle traced in the opposite direction, and the azimuths of these ellipses to be uniformly distributed in all directions in the plane tangent to the wave-front. From interference experiments, however, we know that the elementary wave-trains have, on the average, upwards of a million waves; that is, the form of vibration of each remains the same for upwards of a million vibrations. It follows that the myriads of elementary radiators in a homogeneous source must combine in their effect at any point to produce a vibration there whose form diverges from an ellipse less than does that of the planet of Mercury. In spite of this relative constancy, however, experiments to detect form of vibration in natural light have been in vain, owing to the extremely short time intervals involved (10^{-9} second). Hence, although we are convinced that natural light furnishes at any given moment vibrations of a definite elliptical form, that form is not sufficiently enduring to serve to reveal the

truth of the conclusion, much less to serve as a practical light source of definite vibration form. The method of obtaining a definite and enduring elliptical vibration is to first sift out of natural light rectilinear vibrations of definite azimuth and then, by chosen devices, convert these into the desired elliptical form.

2. *Propagation of Light.*—Various crystalline media, isotropic media subjected to magnetic electric or mechanical stress, and a very large number of liquids possessing an asymmetric carbon atom effect a surprising though simple change in the vibration of the light which they transmit. The explanation of the phenomena is based on the observation that these media possess the remarkable property of transmitting waves of certain vibration characteristics faster than others.[1] By virtue of this property, a wave-train entering such a medium is separated into two component wave-trains, one of which outdistances the other. By choosing conditions so that these two waves are differently refracted, they may be entirely separated. Or in case they are not differently refracted, they will, on emerging into an isotropic medium, combine to form a single wave-train whose ellipticity and azimuth are in general different from that of the entrant train.

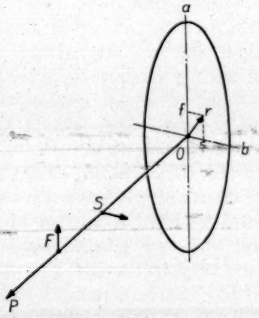
These media fall into two general classes according to the vibration form which they transmit. The first class, known as *plane doubly refracting* media, separates the incident light into two rectilinearly vibrating wave-trains whose vibrations are mutually perpendicular. In "uni-axial" crystals, one of these vibrations, known as the ordinary ray, is transmitted with the same velocity in all directions through the crystal; the other, known as the extraordinary ray, is transmitted with a velocity which in general varies with the direction. In one direction, designated as the *optic axis* of the crystal, the ordinary and extraordinary rays are propagated with equal velocity. In "bi-axial" crystals, there are two equal velocity directions, both rays being extraordinary in that the velocity of both varies in general with the direction. Calcite, mica, a number of liquids normal to the lines of force in an electric or magnetic field, glass under tension or compression, are important examples of this class. The second class is *circular doubly refracting.* It transmits light in the form of two circular vibrations—one whirling around the direction of propagation clockwise, the other counter-

[1] The analogous effects arising from a difference in the absorption of the two components are not treated in this article.

clockwise. Quartz along the optic axis, sugar solutions and liquids generally having an asymmetric carbon atom and substances along the lines of force of a magnetic field, are examples of this class.

3. *Review of Mechanical Theory of Propagation of Elastic Waves.*—While it would be impossible to give, within the scope of an article such as this, even a brief theory of crystal optics, an outline of the fundamental assumptions and conclusions may not be superfluous. Fresnel's mechanical theory of light trans-

FIG. 1.



Shows a single displacement (*Or*) propagated in an elastic medium as two separate displacements (*F* and *S*) respectively parallel to the axes (*Oa*, *Ob*) of the rigidity ellipse in the plane of which the original displacement lies.

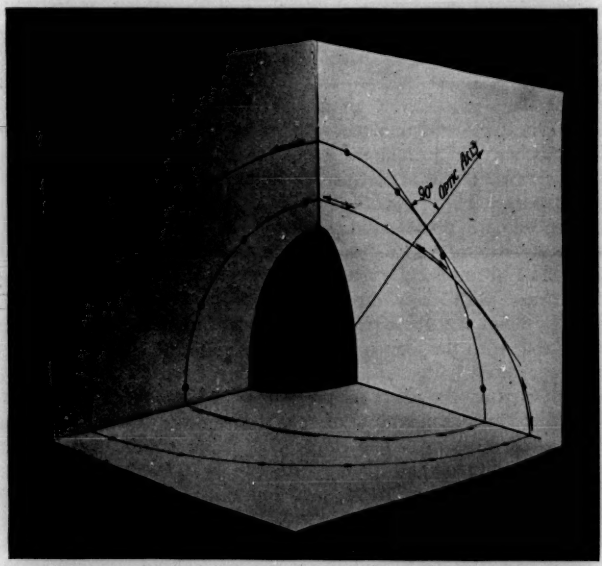
mission gives a relatively simple framework in which the main facts may be coördinated.

Every elastic medium has its "ellipsoid of elasticity," whose semi-axes represent, respectively, the displacements of a particle from its position of rest relative to its neighbors when subjected to a given force in those directions. Every diametral section of that ellipsoid is an ellipse whose semi-axes represent likewise the displacement produced by the same force in their respective directions. For simplicity, we shall use here the corresponding *rigidity ellipsoid* which represents the force of restitution for a given displacement—the velocity of propagation of an elastic displacement through any medium being directly proportional to the square root of its rigidity.

In Fig. 1, *Oab* is a diametral section of the *ellipsoid of rigidity* normal to the direction *OP* of propagation of a transverse dis-

placement *Or*. The component displacement *Of*, parallel to the major axis of the ellipse, is propagated along *OP* with a velocity proportional to the square root of the semi-major axis *Oa;* that parallel to the minor axis is propagated along the same direction

FIG. 2.



Quadrant traces of the ellipsoid of rigidity (in black) and the consequent wave-front traces on the coördinate planes for displacements respectively parallel and perpendicular to the coördinate planes. Displacements perpendicular to the given plane marked by dots; parallel, by double arrows. The medium is bi-axial.

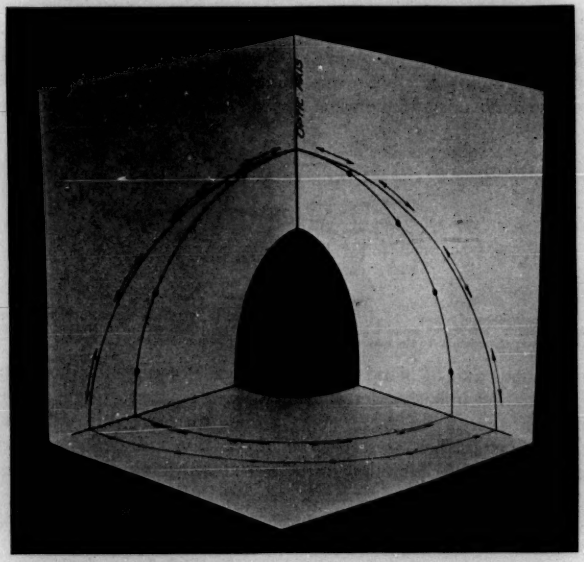
with a velocity proportional to the square root of the semi-minor axis *Ob*. After a given interval, the faster component will have reached *F*, while the slower has only reached *S*. Thus any transverse vibration in the plane *Oab* will be propagated along the direction *OP* as two separate rectilinearly vibrating wave-trains whose planes of vibrations are parallel, respectively, to the major and minor axes of the elliptical section of the ellipsoid of rigidity, whose plane is normal to the direction of propagation. The gen-

eral case of radiation in all directions from a point in an elastic medium is illustrated by Fig. 2, which gives quadrant traces of the two wave-fronts on each of the coördinate planes, the coördinate axes being the semi-axes extended of the ellipsoid of rigidity—shown in black. Vibrations parallel to the major axis of the rigidity ellipsoid (vertical coördinate axis) should obviously be propagated throughout the horizontal coördinate plane with a constant maximum velocity, hence the trace of this wave-front on that plane is circular—marked with dots. Similarly, vibrations parallel to the intermediate and minor axes of the ellipsoid of rigidity have respectively circular traces on the right and on the left vertical coördinate planes—their respective radii representing intermediate and minimum velocities. The vibrations of these three circular traces are all perpendicular to the respective coördinate planes. The wave-front traces of the vibrations parallel to the coördinate planes, indicated by the double arrows, must obviously coincide on the coördinate axes with the like directed vibrations of the circular traces just described, hence their velocity must vary with their direction of propagation in the plane. Theory shows that these traces are elliptical, the axes of the ellipse coinciding with the axes of the rigidity ellipsoid. For directions of propagation lying outside these *principal sections* of the ellipsoid of rigidity the effect may be visualized by imagining Fig. 1 superposed on Fig. 2 with *O* of 1, at the origin of 2, and *OP* given the desired direction. The ellipse *Oab* being a diametral section of the rigidity ellipsoid whose normal is *OP*, determines the direction of vibration in the fast and slow wave-fronts as also their velocity of propagation.

From Fig. 1, it is seen that if the rigidity ellipse becomes a circle, the two component vibrations are propagated along *OP* with equal velocity, hence all components are; as a result, the two wave-trains merge into one. Since there are in general two circular diametral sections of an ellipsoid *and only two,* there should be two directions relative to the rigidity ellipsoid in which the two wave-fronts coincide in their velocity and only two. One of these directions is indicated in Fig. 2 by the intersection of the two wave-front traces in the right vertical plane. The other direction is given by the symmetrically placed point in the second quadrant of the same plane. When dealing with an elastic electrical medium—optical medium—the direction of this intersection from the origin is called the direction of *equal ray velocity.* Since

the velocity of the wave-front is measured along the wave normal, that is, by the perpendicular distance between successive positions of the wave-front, the normal to the tangent plane common to the two wave surfaces at this point gives the direction of *single wave velocity* or the *optic axis*. In general then, a medium possesses

FIG. 3.



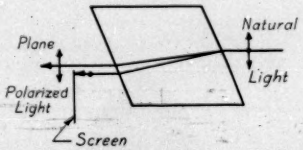
A special case of Fig. 2 where the rigidity ellipsoid (in black) is a figure of revolution, consequently the medium is uni-axial.

two optic axes and only two. When the rigidity ellipsoid is a spheroid, it has but one diametral section which is circular, hence only one direction of equal ray velocity and this coincides with the direction of the single optic axis. Fig. 3 shows the wave-front traces on the coördinate planes for such a medium—the two crossing points in the first and second quadrants of the vertical plane of Fig. 2 merging here into one contact point on the vertical axis—axis of the spheroid. When the ellipsoid of rigidity is a

sphere, all directions are, of course, equal velocity directions, the medium is *optically isotropic.*

Returning to the general case illustrated by Fig. 2, it may be stated that the directions of vibration in the two wave-fronts are determined by the angles which the direction of propagation makes with the two optic axes. From geometrical considerations, it may be shown that *the directions of the component vibrations occupy middle positions between the two planes containing each an optic axis and the wave normal.* Applying this rule to uni-axial media, these two planes merge into a single one, hence the two vibrations lie respectively in and perpendicular to the plane of the optic axis and the wave normal. In the immediate vicinity

FIG. 4.



Application of a plane doubly refracting substance to sift plane polarized light out of natural light. The rhomb causes a larger lateral displacement of the more refrangible component (vibration perpendicular to the plane of the paper) and this is intercepted by a screen.

of an optic axis of bi-axial crystals, this rule requires the direction of vibration in both outer and inner wave-fronts to rotate in the plane of the wave-front in going around the optic axis, and just half as fast. Thus, as seen from Fig. 2, in passing 180° around an optic axis the vibration in its immediate vicinity, on both the outer and inner wave surfaces, changes in direction by 90°.

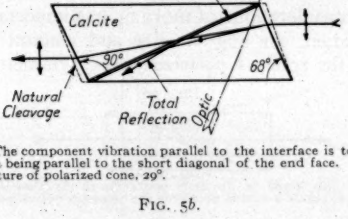
For the large class of substances which propagate light in the form of two opposite circular vibrations differing in their velocity of transmission, a simple mechanical theory is lacking. We shall accept the fact without attempting to explain it and follow it later to a simple conclusion.

III. POLARIZERS AND ANALYZERS.

The single wave-train of an isotropic medium is, in general, separated on entering a medium whose ellipsoid of rigidity is not a sphere, into two differently refracted rectilinearly vibrating wave-trains, one of which under certain conditions may be diaphragmed off. Thus a device is furnished for sifting "plane polarized" light out of "natural" light, as illustrated in Fig. 4.

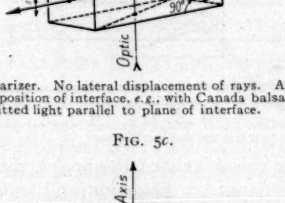
Polarizers of this type were in early use and still are used to a certain extent. The most common polarizing device, however, is the so-called *Nicol prism* (named after its originator, William

FIG. 5*a*.



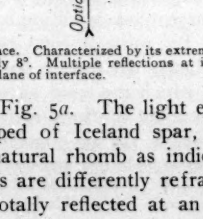
Nicol prism. The component vibration parallel to the interface is totally reflected, the transmitted vibration being parallel to the short diagonal of the end face. The rays are laterally displaced. Aperture of polarized cone, 29°.

FIG. 5*b*.



Glan-Thompson polarizer. No lateral displacement of rays. Aperture of polarized cone varies with slope and composition of interface, *e.g.*, with Canada balsam, 27°; with linseed oil, 35°. Vibration of transmitted light parallel to plane of interface.

FIG. 5*c*.

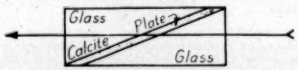


Glan polarizer. Air interface. Characterized by its extreme shortness, 0.9 of its diameter. Aperture of polarized cone nearly 8°. Multiple reflections at interface disturbing. Vibration of transmitted light parallel to plane of interface.

Nicol) illustrated in Fig. 5*a*. The light enters the sloping end face of a parallelopiped of Iceland spar, a uni-axial medium, fashioned from the natural rhomb as indicated. Here the two component wave-trains are differently refracted, after which the more refrangible is totally reflected at an interface of Canada

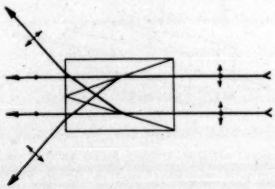
balsam, linseed oil or other suitable material, interposed at the right slope while the less refrangible ray is transmitted with little loss and no refraction. A coat of black paint on the lateral faces of the rhomb absorbs the reflected ray. Other important polarizers of this type are illustrated in Figs. 5*b* and 5*c*. Necessary features of a satisfactory polarizer are perfect polarization and high transmission with also, for colorimetric work, neutral absorption. Other considerations of more or less importance, depending on the application, are angular size and amount of lateral displacement of the cone of polarized rays, symmetry of the same

FIG. 5*d*.



Feussner polarizer. This would be distinctly preferable to the preceding polarizers were it possible to obtain a cement possessing the necessary optical properties.

FIG. 5*e*.



Ahrens polarizer. Effectively a double Glan-Thompson polarizer in which, however, the discarded component is in part transmitted but diverted out of the regular polarized cone.

with respect to the visual axis of the prism, ratio of diameter to length of prism, amount of distortion and astigmatism. All of the Nicol type transmit the so-called extraordinary ray, for which the spar possesses a refractive index varying with the direction of the ray through the crystal; hence a theoretically perfect image through the prism is impossible for any but parallel rays because of the resulting astigmatism—a condition of importance in polarization microscopes.[2] By using a total reflecting plate of spar in a medium of CS_2 Jamin designed a polarizer which transmits the ordinary ray, for which the spar, as well as the CS_2, has a refractive index independent of the direction.[3] Brace used this

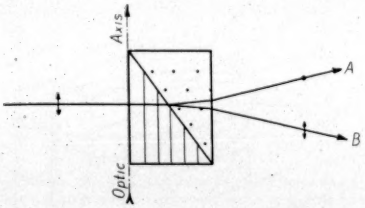
[2] S. Becker, *Ann. d. Physik.* [4], **47**, p. 285 (1915).

[3] This principle has been applied in the so-called Feussner prisms, Fig. 5*d*—Feussner, *Zeitschr. Instrk.*, **4**, p. 41, 1884; and Schulz, *Zeitschr. Instrk.*, **40**, p. 180, 1920—which are consequently free of this kind of astigmatism.

design for producing a very perfect half-shade polarizer, but it, owing to the difficulties of construction and maintenance, has found very limited use.

The need for polarizers of larger cross-section relative to their length than the ordinary design possesses, has led to a built-up type such as shown in Fig. 5*e*, which serves well for some

FIG. 6.



Wollaston polarizing prism. Consists of two equal calcite (or quartz) prisms with their optic axes at right angles to each other and to the visual axis. Incident rays are separated at the interface into plane polarized components equally and oppositely refracted. On emergence each suffers further refraction but not as customarily assumed, exactly equal. Associated with the refraction there is also dispersion, the effect of which needs to be eliminated in its applications.

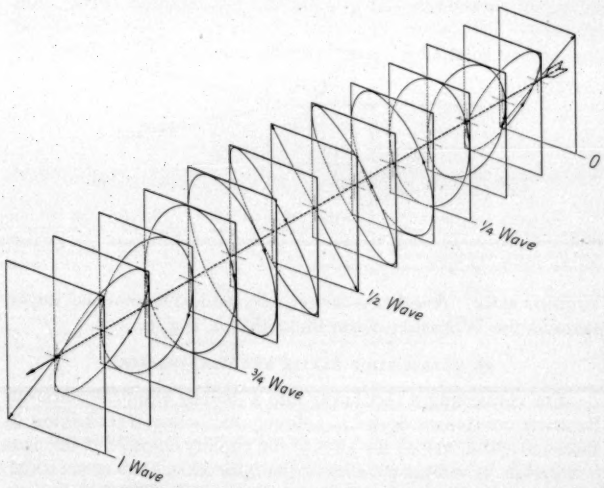
kinds of work. Another polarizer of considerable practical importance is the Wollaston prism illustrated in Fig. 6.

IV. RETARDATION PLATES AND COMPENSATORS.

For converting a rectilinear into a definite elliptical vibration, the most convenient device is a doubly refracting plate having its faces normal to one of the axes of the rigidity ellipsoid if the plate is bi-axial; or simply parallel to the optic axis, if it is uni-axial. Mica is naturally adapted for such purposes because its cleavage plane fulfills the first requirement and polishing is unnecessary. Fig. 7 illustrates the change in form of an incident rectilinear vibration as it is propagated through such a plate—equal or no absorption of the two components being assumed. The problem of determining the elliptical form of the vibration at any point is simply one of the superposition of two mutually perpendicular pendular vibrations both having the same period, each a definite amplitude and the two a definite phase difference. It is readily seen that there are two controlling factors entering into the production of a definite ellipse from the incident rectilinear vibration, namely, the thickness of the plate and its azimuth with respect

to the incident vibration—the first determining the phase difference and the latter the relative amplitudes of the component wave-trains. With an azimuth giving equal amplitudes the maximum ellipse, a circle, is produced by a plate which retards the slow wave-train a quarter wave-length behind the fast; or, three-quarters wave-length; and so on. From the figure, it is seen

FIG. 7.

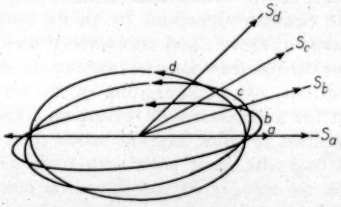


Change in form of an elliptic vibration with distance along the path when the horizontal component is propagated with a greater velocity than the vertical.

that the direction of motion in the circle is opposite in the second case to that in the first. If the *ellipticity* (ratio of axes) in the first is considered to be +1, it is designated as −1 in the second, so that by convention the sign of the ellipticity indicates the direction of motion of the vibrant particle in its elliptical path. By rotating the quarter-wave plate through an azimuth of 90° around the ray, the fast and slow waves are simply interchanged so that the circular vibration produced in the first position becomes, with the plate in the second position, an opposite circular vibration. By varying its azimuth, therefore, a quarter-wave plate will pro-

duce from plane polarized light any ellipticity between +1 and −1. Likewise, a thicker or thinner plate will produce any ellipticity between its maximum and equal minimum as illustrated by Fig. 8. Both the variable-thickness and variable-azimuth methods of

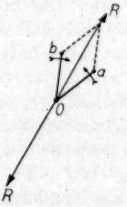
FIG. 8.



Plane polarized incident light vibrating parallel to S_a, on traversing a doubly refracting plate of order less than a quarter-wave, emerges unchanged for an azimuth S_a of the plate; and as the respective elliptic vibrations b, c, d for azimuths S_b, S_c, S_d of the plate. With S_d at 45° (as drawn) to the incident vibration the ellipticity of d is a maximum. With plate azimuths at 90° to those given the paths are unchanged, merely traced by the vibrant particles moving in the reverse direction.

producing a given ellipticity are in common use. It is obvious that a second equal plate at an azimuth of 90° to a first will neutralize any ellipticity produced by the first, hence the same device used for producing a given elliptical vibration will serve

FIG. 9.



A vibrant particle simultaneously subjected to two equal period but oppositely rotating circular displacements (Oa and Ob) traces a rectilinear path (RR) when the two amplitudes are equal. When the amplitudes are unequal the path is an ellipse traced in the direction of motion of the component having the larger amplitude.

to " restore " such a vibration. Such *compensators* are in general use for measuring the constants of polarized light. A quarter-wave plate can be adjusted in azimuth so as to restore an ellipticity of any magnitude from +1 to −1; a plate less or greater than

a quarter-wave may be so placed in azimuth that it will restore any ellipticity between the maximum and equal minimum magnitudes it will produce from plane polarized light.

Two opposite circular vibrations of equal amplitude combine, as illustrated in Fig. 9, to produce a rectilinear vibration of double amplitude; or, *vice versa*, a rectilinear vibration will be propagated as two opposite circular vibrations in media that transmit only circular vibrations. Where these two wave-trains are propagated with different velocities, they may be isolated, in the same way as rectilinear vibrations, by diaphragming or by total reflection, if conditions exist for a difference in refraction. Our interest here is, however, confined to what happens when the two wave-trains are propagated over the same path with merely a difference in velocity. Since, as seen from the figure, a change in relative phase of the two vibrations merely shifts the direction of the resultant rectilinear path, we have in that case a simple rotation of the plane of polarization whose magnitude is proportional to the thickness of the rotating medium traversed. Plates of "right" and "left" rotatory quartz (faces perpendicular to the optic axis) are commonly used as compensators to restore the azimuth of a rotated rectilinear vibration.

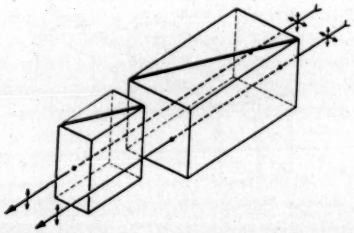
V. AZIMUTH POLARIMETERS.

For precision measurement, the brightness half-shade method is in dominant use. In this, the criterion for a setting is a brightness match of usually two, but sometimes three, contiguous parts of the field of view. This half-shade field is obtained by polarizing the light at two slightly different azimuths in the respective parts to be matched, by using either a Cornu-Jellett "split Nicol" or a Lippich combination of one Nicol covering the whole field followed by a second at a slightly different azimuth covering a part only (Fig. 10). The Cornu-Jellett Nicol (Fig. 11) is in principle a common Nicol from which has been removed a thin, wedge-shaped, central longitudinal section perpendicular to the interface, and the remaining parts closed together, thus furnishing in the respective parts of the field rectilinear vibrations of slightly different azimuth. The Lippich system has the advantage of readily changing the difference in the two azimuths—which changes the brightness and sensibility in opposite directions—but introduces asymmetry in that the second Nicol reduces

the brightness of its half of the field below that of the other. In dealing with purely azimuth measurements, however, this effect is readily eliminated, but not so when ellipticities are involved.

With either of these half-shade polarizers and a monochromatic light source, a setting is made by rotating the analyzing Nicol to a match near the extinction azimuth. It is important to note that the sensibility of this kind of a half-shade is double that of an ordinary photometric field where, in making a setting, the light intensity is varied in one half only. Here, shifting the

FIG. 10.



Lippich half-shade polarizer. By rotating the larger Nicol about the visual axis the azimuth of vibration in the right half of the field is varied at will, while the left half is only changed in amplitude, not in azimuth. By such adjustment the brightness level of the field matched by an analyzing Nicol is readily varied. (Used as an analyzer, the direction of the light is reversed.)

azimuth of the analyzing Nicol from a true setting reduces the intensity of the one part at the same rate that it increases it on the other.

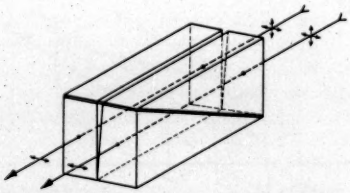
With a heterochromatic source (commonly some definite "White Light" through a specified filter) the dispersive power present in all rotatory substances necessitates the employment of an oppositely rotatory compensator of practically equal dispersing power of the substance under investigation and whose thickness can be varied to compensate for the rotation of the substance. A common form consists of a wedge combination of right and left rotating quartz which compensates rotation in either direction.

Both the rotation and the fixed analyzer types have been brought to such a high state of perfection that under the best conditions careful observers will differ in their determinations by not more than two or three thousandths of a circular degree.

VI. APPLICATIONS OF THE AZIMUTH POLARIMETER.

1. *Saccharimetry.*—By far the most important and most common application of the azimuth polarimeter is in grading the products of the sugar factory for which work it is indispensable. There are upwards of 100 sugars known and nearly all of these in solution rotate the azimuth of a rectilinear vibration in one direction or the other. Commercial sugars are bought and sold and the import duties collected upon tests by this instrument. The simple proportionality between solution concentration and optical

FIG. 11.



Cornu-Jellett half-shade Nicol, showing section removed, after which the parts are closed together giving slightly different azimuths of vibration in the two halves of the field. This design serves equally well as polarizer or analyzer. The more common construction, in which only one of the two parts has a wedge removed, will serve equally well as an analyzer, but introduces ellipticity when used as a polarizer.

rotation, the extreme simplicity of the manipulation, the high precision in measurement and the reliability of the interpretation makes the application so important as to render the situation very serious for the sugar industry as also for the Government laboratory when, as during the war, the possible supply and repair of these instruments is cut off.[4]

2. *Photometry.*—In photometry, and incidentally in optical pyrometry, the principle of the azimuth polarimeter is applied in a unique way. It is obvious that, viewed in the direction of the arrow through the Wollaston prism of Fig. 6, the two separate fields in the respective directions of A and B would appear superposed. By limiting their extent and increasing at the same time their angular position, they may be separated more or less. By employing a device which at the same time eliminates overlapping,

[4] Had the Bureau of Standards not undertaken the repair of polarimeters at one time when the foreign makers were inaccessible and our own optical manufacturers unable to do so, it is difficult to estimate what would have been the consequences of the resultant paralysis to the industry.

they may be juxtaposed under desired conditions. The light from the two respective fields is rectilinearly polarized at right angles so that by interposing a simple Nicol and varying its azimuth a match of the two may be produced. The match azimuth of the analyzing Nicol serves to determine the relative brightness of the two given rectilinear vibrations in the respective sources and of course the relative brightness of the two sources in case they are unpolarized. When the light is partially polarized an additional setting made with the instrument rotated in azimuth through 180° will obviously give the total brightness ratio. This principle was first used by Koenig in his spectrophotometer; is used in the Koenig-Martens spectrophotometer,[5] an improvement on the Koenig, and in the Martens photometer,[6] schematically illustrated by Fig. 12, in which are omitted the lenses and diaphragms necessary to a satisfactory realization of the design. In the spectrophotometer, the light passes through a dispersing prism before entering the Wollaston of Fig. 12, and the windows at *A* and *B* are respective parts of a single slit.[7]

3. *Colorimetry. The Arons Chromoscope.*[8]—In this instrument (Fig. 13) the principle of the azimuth polarimeter is applied to obtain various colors by the selective transmission of "white light." Its range of color production, relative simplicity and independent reproducibility give it a unique position among colorimeters. It is almost universal, failing only to furnish the very pure colors, notably in the red. All mixed colors are reproducible

[5] *Ann. der Physik.* [4], 12, p. 984 (1903).

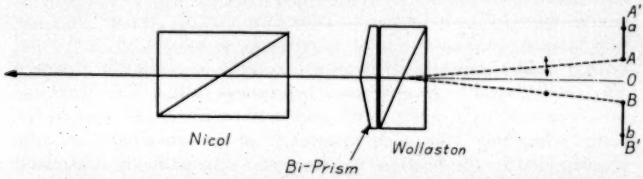
[6] *Physik. Zeitschr.*, 1, p. 299 (1899).

[7] The Colorimetry Section of the Bureau of Standards has compared their Koenig-Martens spectrophotometer with the known transmission of a rotating sector and drawn therefrom the following conclusions: (1) The probable error of a single observation in the brightest part of the spectrum is about 0.007 of the transmission; (2) the probable error of a single observation is about 0.01 of the transmission (for a transmission of 0.37) for homogeneous light ranging from $\lambda_{Hg} = 435.8$ millimicrons to $\lambda_{He} = 706.5$; (3) the actual error of the mean of ten observations is usually less than 0.01 of the transmission for the range $\lambda = 430$ to $\lambda = 700$, for transmissions as small as 0.1. The Optical Instruments Section has compared their Martens photometer, which is used for measuring the transmission of optical glass and optical instruments, with a rotating sector, and found that, based on the average of ten sets of readings each, the error made by three observers in measuring a known transmission of .80 ranged from zero to .005.

[8] L. Arons, *Ann. der Physik.* [4], 39, p. 545 (1912).

beyond one's power of discrimination. The simpler form of the instrument consists of a variable thickness of rotatory quartz placed between two Nicol prisms, the analyzing Nicol being mounted in a graduated circle. Viewing a source of "white

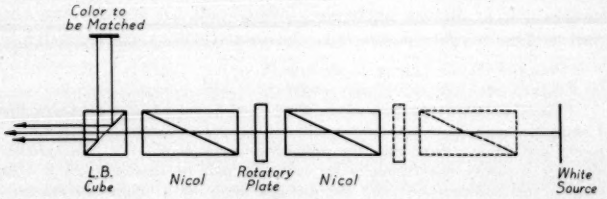
FIG. 12.



Polarization and half-shade elements of the Martens photometer. The Wollaston prism directs to the eye from the field AA' only the vertical components of the light vibrations, and from BB' only the horizontal. The bi-prism brings the two fields into contiguity without overlapping. The Nicol is rotated to a brightness match, its setting giving a measure of the relative brightness of the two fields as determined by the given components. A similar setting obtained on rotating the instrument 180° about its visual axis gives the brightness ratio for the remaining components.

light" through this combination, its apparent color, by virtue of the rotatory dispersion of the quartz, can be changed by rotating the analyzing Nicol and by varying the thickness of the quartz plate. With this simple combination, a limited range of colors

FIG. 13.



Polarization elements of the Arons chromoscope combined with a Lummer-Brodhun comparison cube.

results. Two such combinations in series—obtained by adding a second variable thickness rotatory plate and a variable azimuth Nicol between the polarizer and the light source—make up the complete instrument. With a definite "white light" source, any mixed color can be matched and therefore specified by the respective azimuths of the first and third Nicols relative to the second and the thickness of the two quartz plates.

Aside from its value in specifying and reproducing colors Priest has made an important application of the principle of rotatory dispersion to obtain from a practical light source whose color temperature was 2848° K., a luminosity distribution equivalent to that of a theoretical black-body at temperatures ranging from about 1800 to 24,000° K.[9]

He has made another important application, namely, to produce a variable blue filter for eliminating color differences in heterochromatic photometry.[10]

4. *Pyrometry. Leucoscope Used as an Optical Pyrometer.*—In this,[11] the two contiguous images of a rectangular aperture formed by a Wollaston prism are viewed through an analyzing Nicol and a plate of right or left rotating quartz. In general with a heterochromatic source these differ in brightness and in color. A Nicol interposed between the source and the Wollaston may be adjusted in azimuth to produce a brightness match, and the analyzing Nicol may be adjusted in azimuth to approximate a color match. With a 20 mm. thickness of quartz, one part of the field will be a very pale blue and the other a very pale yellow, neither being recognized as more reddish than the other. This is the criterion for a setting. Other conditions remaining the same, the setting of the analyzing Nicol varies uniquely with the spectral distribution (color temperature) of the source. It may therefore be used as an optical pyrometer where the radiation by the source approximates sufficiently that of the ideal black-body. High precision is not possible, however, because of the necessity of judging quality of color, which is not so reliable as judging equality of brightness. Furthermore, each observer must use his own calibration. Where high precision is not so important as convenience, the leucoscope may prove to be a very useful pyrometer.

VII. ELLIPTIC POLARIMETERS.

1. *Elliptic Compensators.*—Here also, because of their admitted superiority, we shall confine our review to instruments whose criterion for a setting is a brightness match between con-

[9] Priest, I. G., *Jour. Opt. Soc. Am.*, **5**, p. 178 (1921); **7**, p. 78 (1923); B. S. Sci. Paper No. 443 (1922).

[10] Priest, I. G., *Phys. Rev.* [2], **9**, p. 341 (1917); B. S. Sci. Paper No. 443 (1922).

[11] Priest, I. G., *J. O. S. A.*, **4**, p. 448 (1920).

tiguous parts of the field of view—that is to half-shade instruments. All elliptic polarimeters are of the compensator type, in which the given elliptic vibration is "restored" to a rectilinear or definite elliptic vibration either by a variable order (thickness) doubly refracting plate or by a variable azimuth plate. From the azimuth and order of the compensator and the azimuth of the restored vibration, the constants of the given elliptic vibration are calculated. The variable thickness compensator is readily obtained, as illustrated in Fig. 14, by cutting a plane parallel doubly refracting plate into two wedge-shaped parts and pro-

FIG. 14.

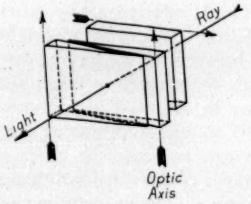


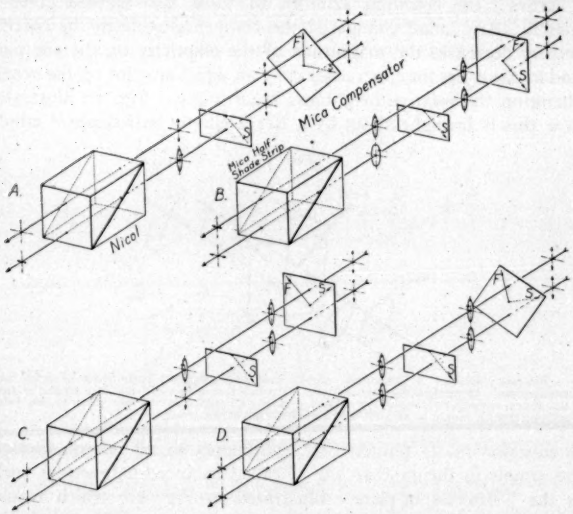
Diagram of Soleil-Babinet compensator for restoring elliptic to rectilinear vibrations.

viding for a measurable relative displacement in this plane. A continuous variation from positive to negative order is obtained through the addition of a second opposing plate, equal in its order to the wedge-pair at some intermediate thickness. This is the principle of the Soleil-Babinet compensator which, however, should not be confounded with the Babinet compensator—a device employing the shift of interference fringes instead of a brightness match.

The variable-azimuth compensator is very simple in design and construction. A uniform sheet of mica, having an order of a quarter-wave, mounted on a graduated circle, makes one which covers all ranges of ellipticity as noted in Section IV. Unfortunately, however, because of dispersion, a quarter-wave plate for one color is effectively less than a quarter-wave for all others—maximum ellipticity being introduced by odd multiples of a quarter-wave relative retardation (Fig. 7). It follows that the use of a variable-azimuth compensator is attended with the necessity of changing compensators when the color is changed.

if maximum range of compensation is desired. Even then, however, the increased uniformity of the field as compared with that of the wedge compensator makes the variable-azimuth type preferable.

FIG. 15.



The Brace half-shade elliptic analyzer. Measures small ellipticities with high precision, but azimuths with low precision. (Order of half-shade strip, .01 to .03λ; compensator, .02 to .06λ azimuth of half-shade near 45°.)

A. Plane polarized entrant light; compensator in neutral position; half-shade strip produces positive ellipticity; viewed through Nicol, lower half of field bright, upper dark.

B. Compensator produces positive ellipticity; half-shade strip augments it; lower half of field of view the brighter.

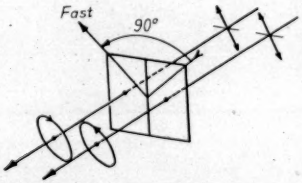
C. Compensator produces negative ellipticity; half-shade strip restores it to a rectilinear vibration; upper half of field of view bright, lower dark—the reverse of "A".

D. Compensator produces negative ellipticity supposedly equal to one-half that in "C"; half-shade strip converts it into an equal positive ellipticity; field of view matched—giving a setting.

2. *Elliptic Half-shades.*—The function of elliptic half-shades is the same as that of azimuth half-shades, namely, to show by an increased brightness of the one part simultaneous with a decreased brightness of the contiguous part, any deviation from the equality of brightness indicative of the correct setting of the compensator. Analogous to azimuth half-shades in which, assum-

ing equal transmission, the rectilinear (equal ellipticity) vibrations in the two parts respectively diverge by equal and opposite amounts from the matched azimuth of the analyzing Nicol, we have in the elliptic half-shade equal and oppositely traced ellipses of practically equal azimuth. The analyzing Nicol set "across" the common azimuth of these two ellipses gives a match. Any small change of the compensator from the correct setting decreases the magnitude of the ellipticity on the one part and at the same time increases it by an equal amount on the other, changing the relative brightness accordingly. Fig. 15 illustrates how this is brought about by a Brace elliptic half-shade [12] which

FIG. 16.



Bravais bi-plate. A "balanced" elliptic half-shade, the two parts being of equal and opposite order—approximately quarter-wave. The function of this half-shade is similar to that of the Brace, namely, to introduce equal and opposite ellipticity in the two parts of the field. Working azimuth should be small to avoid too high brightness levels.

is superior in its photometric fulfilments to all others, though less simple in theory than the so-called balanced half-shades such as the "Bravais bi-plate" illustrated in Fig. 16, which would be an ideal elliptic half-shade were it not impossible to obtain a vanishing dividing line between the parts of the field. With azimuth half-shades, the half-shade system is commonly a fixed part of the polarizing system, but not necessarily so, it might just as well be a fixed part of the analyzing system. On the other hand, while the elliptic half-shade can be a fixed part of either polarizer or analyzer, it is more commonly a part of the analyzer. The brightness level of the elliptic half-shade (which, like that of the azimuth half-shade, determines its sensibility) is readily varied from zero to a maximum by changing its azimuth, relative to the Nicol, from zero to 45°. The Brace half-shade is best when its order is so small as to require it to be used at the 45°

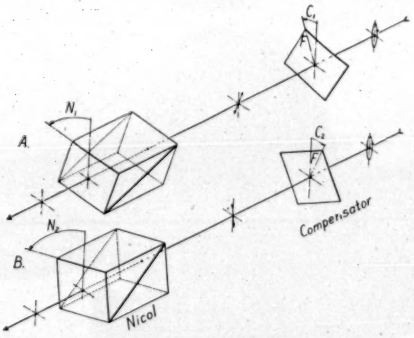
[12] Brace, D. B., *Phys. Rev.*, **18**, p. 70 (1904); **19**, p. 218 (1904).

azimuth, while the Bravais bi-plate must generally be used at a much smaller azimuth.

VIII. A GENERAL POLARIMETER.

For the combined determination of azimuth and ellipticity Tool's application of the Brace elliptic half-shade to the Stokes' method of analysis is the most accurate. In the Stokes' method [13]

FIG. 17.



The Stokes elliptic analyzer.

A. The compensator and Nicol are adjusted to give minimum intensity of field (restored polarization) and their respective azimuths C_1 and N_1 recorded.

B. The same is repeated with the compensator at a complementary azimuth—observed values C_2 and N_2.

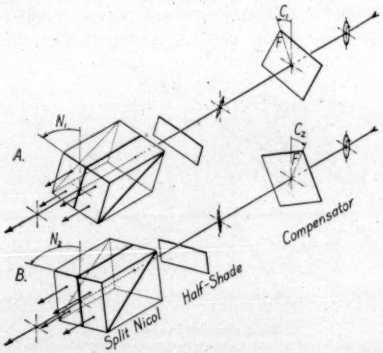
From the four azimuths C_1, C_2, N_1 and N_2, both the ellipticity and the azimuth of vibration of the entrant light is determined. Will not measure a circular vibration.

(Fig. 17), the given elliptic vibration whose azimuth and ellipticity are sought, is restored to a rectilinear vibration by passage through a mica plate, for example, first in one azimuth, then in its complementary azimuth. The analyzing Nicol is set for extinction on the two restored vibrations, the corresponding azimuths of the compensator being observed. From the complementary azimuths of both Nicol and compensator, the azimuth and ellipticity of the given elliptic vibration is calculated in a relatively simple manner, in which process the order of the compensator does not need to be known. While this method is extremely simple, it is not so accurate as generally desired. By substituting a Cornu-Jellett half-shade Nicol for the simple analyzing Nicol

[13] Stokes, C. G., *Phil. Mag.* [4], **2**, p. 420 (1851).

of Stokes and fixing to this a Brace elliptic half-shade so as to give a four-part field, Tool [14] makes complementary settings for a four-part match of the field, and carries out computations analogous to those of Stokes to obtain the constants of the given elliptic vibration. This instrument is diagrammatically illustrated in Fig. 18. With a balanced elliptic half-shade, the formula used would be the same as that for the Stokes instrument;

FIG. 18.



Tool's azimuth and elliptic half-shade combination. Replaces the Nicol in Stokes' method with a Cornu-Jellett half-shade Nicol to which is attached a Brace elliptic half-shade. Complementary settings (*A* and *B*) for a match of the four-part field are made and computations analogous to Stokes' carried out. The compensator restores the given ellipticity, not completely, but to a definite small magnitude and the half-shade Nicol locates its azimuth.

but with a Brace half-shade, it is more complicated, requiring the order of the half-shade to be either negligible or known. Tool's measurements indicate for this instrument an accuracy better than 1 per cent. when measuring ellipticities of the magnitude of .02; and an accuracy of .05 per cent. in measuring circular vibrations—where the Stokes instrument fails.

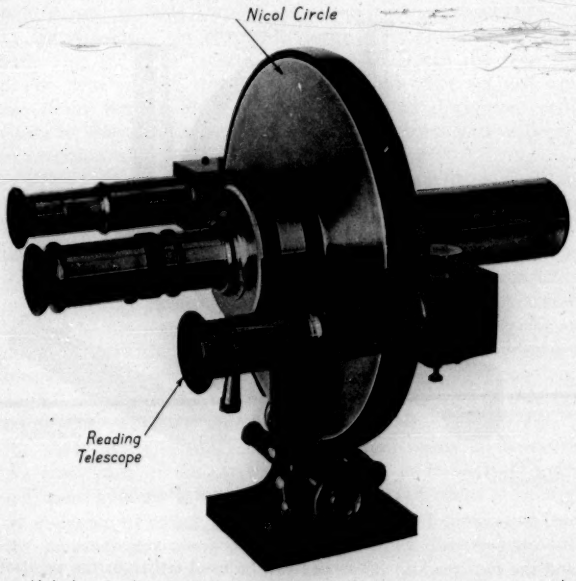
IX. A UNIVERSAL POLARIMETER.

There has been recently designed and constructed at the Bureau of Standards a polarimeter (Figs. 19*a* and *b*) which is readily convertible into a convenient form for making any of the special measurements reviewed above. For purely azimuth measurements

[14] Tool, A. Q., *Phys. Rev.*, 31, p. 1 (1910).

of plane polarized light, Tool's general polarimeter would obviously be too cumbersome. Furthermore, for measuring small ellipticities without reference to their azimuth, the Brace type is much more convenient than that of Tool. A detailed description and working theory of this *universal polarimeter* is to be pub-

FIG. 19a.

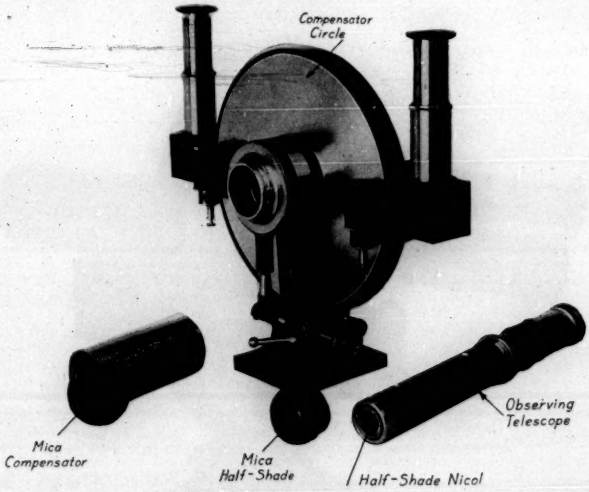


Assembled view of universal polarimeter designed to be mounted on the telescope arm of a spectrometer.

lished shortly so that a brief enumeration of its features will suffice here. As shown in the figures, it is assembled as a Tool polarimeter. The light to be measured is passed, as in Fig. 18, first through a mica compensator carried by the "compensator circle" (which is graduated on its edge), then through the mica elliptic half-shade and half-shade Cornu-Jellett Nicol mounted together on the extended end of the observing telescope

which is carried by a similar "Nicol circle." These two circles are respectively supported on the two ends of a central hub provided with a single pair of Vernier arms, each arm having two Verniers, one for each circle, reading to .01°. Both circle scales are in the field of view of the reading telescope at the same time,

FIG. 19*b*.



Disassembled view of same reversed.

and the two reading telescopes can be used either in the position of 19*a*, by the observer, or in the position of 19*b* by an assistant. Slow motion of both circles is provided by the tangent screws at the base. To convert the instrument into a Brace elliptic polarimeter, the half-shade Nicol is replaced by a simple Nicol and a thin compensator used. To convert it into an azimuth polarimeter for rectilinear vibrations, the elliptic half-shade and compensator are both removed and a half-shade Nicol placed in either the analyzing or polarizing end of the system.

X. APPLICATIONS OF THE GENERAL POLARIMETER.

1. *Determination of the Optical Constants of Absorbing Media.*—One of the most important applications of the general polarimeter is in determining the refractive indices, absorption constants and reflecting power of metals and other highly absorbing materials capable of being given a mirror polish. This development, which the electromagnetic theory of light brought with it, was perhaps Drude's major contribution to physics.

By measuring the change in form of vibration which light suffers on reflection from a mirror, not only can the reflecting power be determined with an accuracy which other methods cannot attain, but also the refractive indices and absorption coefficients of the material can be deduced therefrom with a degree of precision which no other method can approach.

The method may be sketched as follows: Plane polarized light with its azimuth at 45° to the plane of incidence falls on the mirror at a definite angle. The azimuth and ellipticity of the reflected light is measured, and these magnitudes, together with the angle of incidence, serve to calculate the desired constants.

The change in azimuth arises from the component vibration parallel to the plane of incidence having a reflection coefficient different from the component perpendicular to it. Transparent media show a similar effect as illustrated by the "polarizing angle" at which the parallel component has a zero reflection coefficient. The change in ellipticity arises from a difference in the phase loss (or gain) of the two components on reflection. An application of the corresponding effect in transparent media is Fresnel's rhomb in which by two internal reflections at an angle of incidence of about 51° in glass, the parallel component leads the perpendicular component in phrase by a quarter-wave—the rhomb thus serving as a quarter-wave plate.

The theory of the method for absorbing media is not simple, owing to the refractive index—and consequently also the *extinction* coefficient—varying with the angle of incidence. That such a variation is possible is readily appreciated from the fact that Fresnel's theory requires the direction of the ray in a transparent isotropic medium to be slanting to the wave-front instead of normal to it, if the amplitude of vibration varies along the wave-front. In an absorbing medium such a condition results from

different parts of the same wave-front having traversed different depths of the medium for other than normal incidence.

The reliability of the polarimetric method for determining the reflecting power of mirrors has been tested by Tate [15] for normal incidence and by Wilsey [16] for both components at slanting incidence.

2. *Mechanical Stress Analysis.*—The phenomenon called forth by mechanical stress is known as "accidental double refraction." It was discovered by Brewster in 1816 and the first application made by Maxwell to study stress in the plane of a strained plate. In general, an isotropic solid such as glass becomes doubly refracting when subjected to stress. By compressing it in a direction at right angles to a ray passing through it, both the component vibration perpendicular to the direction of the compression and that parallel to it are usually slowed up in their velocity of propagation, the former more than the latter. On substituting a tension for the compression, the effect is exactly reversed, both components are accelerated in velocity, that at right angles to the tension, the most.

The result in general is that rectilinearly polarized entrant light is propagated through strained glass as two rectilinearly vibrating wave-trains, one with its azimuth in the direction of the stress and the other at right angles to it. The higher velocity train gains on the other by an amount proportional both to the thickness of the plate and to the magnitude of the stress. The emergent light becomes thus elliptically polarized, its form and azimuth serving to measure the magnitude and direction of the simple stress. In practical applications, the problem seldom has to do with a simple stress.

The purely mechanical methods by which an experimental solution of stress problems is attacked are both difficult and often questionable in their results. One has to assume at the start that the stress is proportional to the magnitude of the strain. This principle can hold only within the elastic limit of the material. Beyond the elastic limit, these methods fail entirely. Furthermore, stresses within the body cannot be measured by mechanical devices. The optical method has proved to be, there-

[15] Tate, J. T., *Phys. Rev.* [1], **34**, p. 321 (1912).
[16] Wilsey, R. B., *Phys. Rev.* [2], **8**, p. 391 (1916).

fore, very acceptable, though it is unable to furnish alone a solution of the problem. Happily, any combination of stresses in a plane at any point may be represented by an ellipse in that plane whose axes give the direction and magnitude of the so-called principal stresses. A ray of light passing through the strained medium perpendicular to the plane of this ellipse is propagated as two rectilinearly vibrating wave-trains whose vibrations are respectively parallel to these two principal stresses. The difference in velocity of propagation of these two trains has been found to be simply proportional to the *difference of the principal stresses,* so that the optical method furnishes a measure of *this difference only,* not of the stresses themselves. If the circumstances dealt with are of a nature such that Poisson's ratio can be applied to determine the *sum of the stresses,* then the two determinations together serve to solve the problem.

During the last few years, this subject has been attacked with vigor and with a very satisfactory measure of success by a number of investigators, among whom are Professors Filon and Coker and Major Low of England, and M. Mesnager of France.

A discovery which has proved to be specially contributory to this success was made by Coker, that xylonite (celluloid) is a very satisfactory material to use for the purpose. It lends itself especially well to both the optical and mechanical determinations, in that it possesses large accidental double refraction and can readily be worked into form. An appreciable "skin effect" is perhaps its worst feature.

Perhaps the most notable application of optical stress analysis has been made by Mesnager who, from a glass model, made a determination of the stress distribution in a bridge of reinforced concrete to be placed over the Rhone at Balme.

3. *Optical Homogeneity of Glass.*—Optical glass, especially molded pieces, is found to be bi-refringent if it has not been properly annealed. If very bad, the piece will crack in cooling or under the process of grinding. If not so bad, the refracting or reflecting surfaces may simply be distorted in the grinding and polishing, thereby giving poor images. If neither of these troubles arises, there still remains the possibility of a "fuzzy" image—though it may be open to question whether the fuzziness observed is due to strain or arises from other inhomogeneities. In any case, whatever the immediate effect, it remains that the

presence of imperfect annealing is readily revealed in both quality and degree by polarimetric measurements, and such measurements are used for determining the acceptability of glass for optical purposes.

XI. SUMMARY.

A review of those fundamental facts and relations concerning polarized light with which the reader should be familiar is given. The devices which serve as the polarization elements of all instruments are then described, followed by a description of half-shade azimuth polarimeters, elliptic polarimeters, Tool's general polarimeter, and a Universal polarimeter designed at the Bureau of Standards.

The practical applications of polarimeters to saccharimetry, photometry, colorimetry, pyrometry, determination of the optical constants of absorbing media, mechanical stress analysis and testing of the optical homogeneity of glass are all briefly described.

The Mechanism of "Dry Corrosion."—Under this term is to be understood the corrosion of metals exposed to air, but protected from rain. The subject has been investigated by U. R. Evans, whose paper has been published by the Faraday Society, as part of a symposium on corrosion of industrial metals. The metals examined were roughened with emery. No corrosion occurred when kept over sulphuric acid, and very little when kept over water. The rate of attack is much increased if volatile electrolytes are in the air, sulphur dioxide being especially dangerous to iron and nickel, ammonia to copper, hydrogen chloride to zinc and aluminum. Hydrogen sulphide and carbon dioxide increase somewhat the rate of rusting of iron, but only superficial changes on other metals.

Evans thinks that the change is due mainly to the influence of the film of moisture on the surface of the metal. This is, of course, invisible, but generally present. Volatile electrolytes increase the conductivity of the film because they are absorbed by it, and as in many cases they may tend to form hygroscopic compounds, the thickness of the film will be increased. In some cases (zinc in hydrogen chloride, copper in ammonia, nickel in sulphur dioxide) the metal originally dry soon begins to shed moisture, and in such cases, corrosion is serious.

The paper was subjected to discussion by several persons, and some exception was taken to the author's statements and conclusions.

H. L.

THE PRESSURE EFFECT AND OTHER PHENOMENA IN GASEOUS DISCHARGES.*

BY

IRVING LANGMUIR, Ph.D.

Research Laboratory, General Electric Company.

WHEN an electric discharge of rather high current density is passed through a monatomic gas at low pressure, the gas tends to move towards the anode and causes the pressure at the anode to exceed that at the cathode. This pressure effect has been observed and studied by L. Hamburger,[1] F. Skaupy[2] and A. Rüttenauer.[3] Hamburger and Skaupy have attempted to explain the motion of the gas to the anode by assuming the presence of negative ions having a mobility higher than that of the positive ions. Skaupy,[4] in a later paper, considers that the effect may be due to the fact that electrons make elastic collisions with atoms while positive ions make inelastic collisions. Thus he assumes that the electrons deliver twice their momentum to gas molecules (because they rebound), while the positive ions cannot deliver more momentum than corresponds to their velocity. A little analysis shows, however, that there is a fallacy in this argument since the rebounding electrons would subsequently collide with other atoms and thus deliver momentum in the opposite direction. In fact, it is readily seen that the effect is thus neutralized. Since positively and negatively charged particles must be present in equal numbers in any uniformly ionized gas, the momenta delivered by the electric force to the positive and to the negative particles in each unit of time must be equal and opposite. Thus, *as long as the particles remain in the gas,* there is no resultant force acting on the gas.

Hamburger's and Skaupy's experiments have been cited by Franck and Grotrian[5] as evidence for the existence of negative ions in discharges in such gases as argon, which have been thought to have no appreciable electron affinity.

Let n_e, n_p and n_n be respectively the number of electrons, positive ions and negative ions per unit volume and let v_e, v_p and v_n be the corresponding average velocities parallel to the axis

* Communicated by the Author.

of the discharge tube. Then, since there can be no appreciable space charge in any uniform positive column,

$$n_e + n_n = n_p, \tag{1}$$

assuming that both the positive and negative ions are univalent. If i is the current carried by the discharge then (taking all velocities positive)

$$i/e = n_e v_e + n_n v_n + n_p v_p. \tag{2}$$

The number of molecules of gas which drift towards the anode through any given cross-section is $n_n v_n - n_p v_p$. Thus if $n_n v_n$ is greater than $n_p v_p$, the gas will be carried electrically towards the anode. As the pressure at the anode increases, gas flows back through the tube to the cathode, but the viscosity of the gas makes it necessary for the pressure at the anode to rise to a certain limiting value before a steady state is reached. Experiments have usually shown [6] that the mobility of negative ions is somewhat larger than that of positive ions, but the difference is not large, the ratio of the mobilities ranging from 1.0 to 1.6. Thus to cause an increase in pressure at the anode, n_n would have to be at least 60 per cent. of n_p. It is well known that electrons attach themselves to molecules in electronegative gases such as oxygen at high pressures, but the data of Townsend,[7] Loeb [8] and others seem to indicate that there is no such tendency in the inert gases. However, in these experiments negative ions would have been detected only if the current carried by the negative ions had been appreciable in comparison with that carried by electrons. The mobility of the electrons in argon may be assumed to be of the order of magnitude of $\sqrt{1834 \times 40}$, or 271 times that of the ions. Thus we may assume as an example within the range of possibility: $v_e = 271 v_p$; $v_n = 1.6 v_p$; $n_n = 0.7 n_p$ and thus find by Equation (1) that $n_e = 0.43 n_n$ and by Equation (2) that the current carried by negative ions ($n_n e v_n$) is only 0.014 of that carried by electrons ($n_e e v_e$), even under these conditions which would cause gas to accumulate at the anode. Although it appears *probable* from the work of Townsend and others that the current carried by negative ions in argon is much less than 1 per cent. and therefore cannot explain the pressure effect in this gas, yet it cannot be said that the experiments have proved this point.

In connection with a study of the positive column of the mercury arc, the writer has, however, developed a theory capable

of explaining the increase of pressure at the anode without the necessity of assuming negative ions. By measuring the volt-ampere characteristics of small electrodes in the path of the discharge, at low pressures, such as ten bars, it has been found that the electrons in a given volume move nearly in random directions with an average kinetic energy which is independent of the current density in the arc (in the range from 0.1 to 1.0 ampere per square centimetre) but which depends on the mercury vapor pressure as shown in Table I.

TABLE I.

Kinetic Energy of Electrons in the Mercury Arc.

Temp. of Mercury.	Pressure of Vapor. Bars	Average Kinetic Energy. Volts	Equivalent Temp.
15°C.	1.0	3.9	30000°K.
32°C.	4.4	2.9	22400°K.
60°C.	33.	1.7	13900°K.

The third column gives the potential difference through which electrons must fall to acquire a kinetic energy equal to the average kinetic energy of those in the arc. The distribution of velocities about the mean has been found to correspond to that given by Maxwell's law. The kinetic energies of the electrons are thus the same as those of molecules in gases at the temperatures given in the fourth column.

A negatively charged electrode in the ionized gas of the arc repels electrons from its neighborhood, so that there is a positive ion sheath around the electrode.[9] By calculation from the space charge equations, it is found that the thickness of this sheath is usually not more than about 0.1 mm. The sheath acts as an electrostatic screen so that the field due to the negative charge on the electrode does not extend beyond the edge of the sheath. All positive ions that reach the sheath are attracted to the electrode. If the electrode is large compared to the sheath thickness, the positive ion current that flows to the electrode is thus practically independent of the applied voltage, and is a true measure of the *positive ion current density* I_p in the arc.

When the electrode is positively charged and the gas pressure is not too high, an electron sheath is formed in a similar manner and the electron current over a certain range is nearly independent

of the applied voltage and is a measure of the *electron current density* I_e in the surrounding space.

The ratio $I_e : I_p$ is nearly the same at different current densities or mercury vapor pressures and averages about 340 : 1. The value of I_e may be too low because of the reflection of some electrons, whereas ions are apparently not reflected to an appreciable degree.

If the kinetic energy of the electron is the same as that of the ions, the ratio should be equal to $\sqrt{200 \times 1834} = 605$. The experiments prove conclusively, however, that the current carried by electrons in the mercury arc is *at least* 340 times that carried by positive ions.

The glass wall of the tube (or any isolated electrode) must acquire such a potential that it receives the same number of negative and of positive charges. Thus it must be sufficiently negatively charged to repel at least all but one electron out of every 340 that move towards it. To do this the walls need to have a negative potential with respect to the surrounding space, which, according to the Maxwell law, is roughly four times the potential corresponding to the average energy of the electrons; according to Table I the walls will thus be from 7 to 16 volts negative, depending on the mercury vapor pressure. It is clear that very serious errors are made by attempting to measure potentials in ionized gases by using sounding electrodes.*

There are, however, two simple methods by which the true space potentials can be measured. In the first method a tungsten filament is used as sounding electrode, so arranged that it can be heated when desired. The filament is first heated to a temperature just below that at which there is appreciable electron emission, but a key is arranged to short-circuit a part of the resistance in series with the filament and thus momentarily raise its temperature to a point where it is capable of emitting an easily measurable current. The potential of this hot sounding electrode is then varied and at each potential it is noted whether or not the current

* Because of this error arising from the use of sounding electrodes, measurements of the anode drop have been altogether too high. In the mercury arc the anode drop is usually about 2 to 3 volts, whereas measurements with ordinary sounding electrodes show 10 to 18 volts. In some cases the anode drop is actually a few volts negative. The conditions at the anode and cathode will be discussed in subsequent articles.

to it changes when the temperature is altered by pressing the key. It is evident that the electrons emitted from the filament can escape only when there is an accelerating field around it. The filament is at the same potential as the space when the electrons are just able to escape. Small corrections need to be made for the voltage drop along the filament and for the initial velocities of the electrons emitted.

The second method consists in measuring the volt-ampere characteristics of a cold sounding electrode, preferably of such large size that its dimensions are fairly large in comparison with the thickness of the electron sheath that forms about it when it is positively charged. As the potential of the electrode is raised, starting from negative values, it first takes up positive ions, then also takes up high velocity electrons. At some definite potential it takes up all the electrons moving toward it (except those reflected); a further increase in potential causes no increase in electron current except as a result of an increase in the sheath thickness. By plotting the current on semi-logarithmic paper against the potential, it is thus found that there is a definite kink in the curve at the point when the electrode potential is the same as that of the surrounding space. This method is found to give results in good accord with those obtained by the hot sounding electrodes and both methods prove that the wall of the tube, or any electrode to which no current flows, is negatively charged with respect to the surrounding space by an amount usually ranging from 5 to 15 volts.

All but a minute fraction of the electrons moving toward the wall are thus *elastically reflected* in the positive ion sheath near the glass surface and are unable to deliver energy to the wall. Direct experimental measurements of the number of electrons striking the wall and comparison with the power consumed by the arc prove that 99.7 per cent. of the electrons moving towards the wall are reflected, and that these electrons lose less than 0.5 per cent. of their energy by such reflection. At first sight it would seem that the reflection should be specular, that is, that there should be no change in average momentum parallel to the axis of the tube. Experiments which will be described in a subsequent paper seem to prove, however, that the reflection is about 30 per cent. diffuse, the collisions of an electron with the wall having the effect of reducing the average longitudinal velocity component

by about one-third. This effect is made manifest particularly by the action of transverse and longitudinal magnetic fields, which change the number of collisions of electrons with the walls, without altering the number of collisions with gas atoms. It is perhaps possible that the diffuseness of the reflection is due to the fluctuations of the positive ion space density in the sheath resulting from statistical causes.

Both theory and experiment, however, indicate that the positive ions are absorbed by the wall and deliver to it all their energy and momentum.

HEATING OF THE WALL BY POSITIVE IONS.

Let us assume that the electrons and the positive ions have an average kinetic energy corresponding to a voltage V_0. Let I_p be the current density of positive ions striking the wall (amperes per cm.^{2}). There will be an equal number of electrons striking the wall to neutralize the charges of the ions. The energy corresponding to the ionizing potential (10.4 volts) will be liberated presumably in the form of heat when the positive ion and the electron combine. Let V_s be the potential drop through the sheath, near the glass surface. The energy carried to the wall by the positive ion in the form of kinetic energy thus corresponds to $V_s + (4/3)V_0$. The factor 4/3 comes from the fact that the kinetic energy of particles passing a given plane ($2kT$) is 4/3 times as great as that of the particles in a given volume (3/2) kT. The energy of the electrons striking the walls is (4/3) V_0. The total energy corresponds to $10.4 + V_s + (8/3)\ V_0$ volts.

In an experiment with a four-ampere arc flowing through a tube 3.2 cm. in diameter with mercury vapor at a pressure of 1.0 bar, the positive ion current density I_p was found to be 0.0011 ampere per cm.^{2} Taking $V_0 = 3.9$ volts, from Table I, and $V_s = 16$ volts, we should get a heating effect corresponding to 37 volts. Thus 37×0.0011, or 0.042 watt, should be liberated as heat on each square centimetre of tube surface as a result of the positive ion bombardment. As the voltage drop in the arc was 0.24 volt per centimetre, the total energy per second generated in the arc per square centimetre of wall was 0.095 watt. Thus 44 per cent. of the power consumed in the arc path was liberated on the walls as a result of the positive ions striking the walls.

At higher mercury vapor pressure the percentage of heat thus carried to the wall decreased and it also decreased as the arc current decreased. Thus in a six-ampere arc with a pressure of 15 bars, 23 per cent. of the energy consumption was caused by positive ions, but at the same pressure with an arc current of one ampere, the percentage was only 15.

PRESSURE EFFECT DUE TO POSITIVE ION IMPACTS ON WALLS.

The positive ions that strike the wall of the tube have an average velocity component v_x in the direction towards the cathode. Let m_p be the mass and e the charge of a positive ion. The force p_x exerted by the ion impacts on each unit area of the inner surface of the tube in a direction towards the cathode is thus

$$p_x = \frac{\varepsilon m_p v_x I_p}{e} \tag{3}$$

since the number of ions striking unit area per unit time is I_p/e. The factor ε is a number less than unity which represents the degree to which the reflection of the electrons by the wall may be regarded as being specular. This factor seems to be approximately of the order of 0.3.

The reaction from this force p_x must be exerted in the gas and must tend to cause an increase in pressure at the anode. It is easy to understand the mechanism of this reactive force. We have seen that the forces due to impacts of ions and electrons against atoms must balance one another in any mass of ionized gas containing equal numbers of positive and negative charges, as long as all the accelerated particles remain within the gas. But when positive ions leave the gas the impact of the electrons against the atoms, producing a force acting towards the cathode, is no longer balanced by the impacts of the positive ions against the atoms.

If the gas pressure is so low that the normal mean free path λ_n is large compared to the radius r of the tube, the gas moves towards the anode until the increase in pressure there balances the force due to p_x, but at higher gas pressure the force p_x causes the gas near the wall to move towards the anode while the gas near the axis of the tube will move in the opposite direction, the increase in pressure at the anode being thereby decreased.

At higher pressures the reactive force due to the positive ion impacts on the wall may thus be assumed to be exerted on the

gas at a distance $r-\lambda$ from the axis of the tube; the gas at this point will have the greatest velocity towards the anode. Let v be this velocity. Then between r and $r-\lambda$ the volume of gas flowing per unit time will be $\frac{1}{2}v\pi[r^2-(r-\lambda)^2]$. If no gas should flow back along the axis of the tube (because of the increased pressure near the anode), the volume of gas flowing per unit time between 0 and $r-\lambda$ would be $v\pi(r-\lambda)$.[2] But by Poiseuille's law, the volume of gas per unit time that flows back because of the pressure gradient is $\frac{\pi}{8}\frac{(r-\lambda)^4}{\eta}\frac{dp}{dx}$, where η is the coefficient of viscosity. In a steady condition with a discharge tube closed at the end, the total amount of gas flowing through the tube must be zero, so that we have

$$v = \frac{r^2}{8\eta}\left(1-\frac{\lambda}{r}\right)^3\frac{dp}{dx} \tag{4}$$

if we neglect $\frac{1}{2}\lambda^2$ in comparison with r^2.

Besides the force p_x (per unit area) acting on the wall of the tube due to the impact of positive ions, there is also a force p_a due to the impact of neutral atoms because the gas at $r-\lambda$ is moving towards the anode with the velocity v. The number of atoms per unit area per unit time striking the wall of the tube is $p\,(2\pi MRT)^{-\frac{1}{2}}$ and of this the fraction $(r-\lambda)/r$ may be assumed to have come from the region where the velocity is v. Thus we find

$$p_a = pv\left(1-\frac{\lambda}{r}\right)\sqrt{\frac{M}{2\pi RT}}. \tag{5}$$

Here M is the atomic weight of the gas and R is the gas constant per gram molecule 8.37×10^7 ergs per degree.

The actual force per unit area acting on the wall of the tube is thus p_x-p_a and this multiplied by the circumference of the inside of the tube must be equal to the pressure gradient multiplied by the cross-section, so that

$$r\frac{dp}{dx} = 2\,(p_x-p_a) \tag{6}$$

Eliminating v and p_a from Equations (4), (5) and (6) and solving for $\frac{dp}{dx}$, we find

$$\frac{dp}{dx} = \frac{2p_x/r}{1+\frac{rp}{4\eta}\left(1-\frac{\lambda}{r}\right)^4\sqrt{\frac{M}{2\pi RT}}} \tag{7}$$

This equation is derived for the case that the pressure is so high that λ_n is smaller than $\frac{1}{2}r$. At lower pressure where $\lambda_n > r$, the equation reduces to

$$\frac{dp}{dx} = \frac{2p_x}{r} \tag{8}$$

To calculate p_x we need to know the velocity component v_x of the ions in the direction of the field.

The time taken by an ion to travel a free path λ with the velocity Ω is λ/Ω. If γ is the acceleration due to the field, then the velocity component in the direction of the field, acquired during the average path, is given by

$$\frac{dx}{dt} = \frac{\gamma\lambda}{\Omega} \tag{9}$$

This equation has been derived by G. Hertz [10] for the velocity of drift of electrons in a field. Because of the persistence of velocities of the ions after collisions [11] this should be multiplied by 1.26. Since the acceleration is $(e/m_p)(dV/dx)$, we have

$$v_x = 1.26\,\frac{e\lambda}{m_p\Omega}\,\frac{dV}{dx} \tag{10}$$

The average velocity Ω of the ions in a given volume may be calculated from V_o, the potential corresponding to the average kinetic energy of the ions in a given volume by the relation

$$\Omega = \sqrt{\frac{16\,V_o e}{3\pi\,m_p}} \tag{11}$$

Combining Equations (10) and (11)

$$v_x = 0.96\,\lambda\sqrt{\frac{e}{m_p V_o}}\,\frac{dV}{dx} \tag{12}$$

and by Equation (3)

$$p_x = 0.96\,\varepsilon\lambda I_p\sqrt{\frac{m_p}{eV_o}}\,\frac{dV}{dx} \tag{13}$$

If we express p in dyne cm.$^{-2}$, x and λ in cm., I_p in amps. cm.$^{-2}$, V in volts, and insert the values $e = 1.591 \times 10^{-20}$ e. m. units and $m_p = M \div 6.06 \times 10^{23}$, the equation becomes

$$p_x = 9.80\,\varepsilon\lambda I_p\sqrt{\frac{M}{V_o}}\,\frac{dV}{dx} \tag{14}$$

In this equation, as well as those immediately preceding, λ is not the normal free path which would occur in a large volume, but is the average actual free path which at low pressures is limited by

the wall of the tube. Where λ_0 is larger than r, the value of λ should then be put equal to $2r$, the diameter of the tube.

The pressure effect may now be calculated by combining Equations (14) and (8)

$$\frac{dp}{dx} = 18.6\,\mathfrak{E}\,I_p \frac{\lambda}{r(1+\rho)} \sqrt{\frac{M}{V_0}}\,\frac{dV}{dx} \tag{15}$$

where for convenience the second term in the denominator of the second number of Equation (7) has been represented by ρ. Putting in the numerical value of R, we thus have

$$\rho = 1.09 \times 10^{-5} \frac{rp}{\eta}\left(1 - \frac{\lambda}{r}\right)^4 \sqrt{\frac{M}{T}}. \tag{16}$$

Rüttenauer measured the pressure effect in helium and argon at pressures ranging from 700 to 1200 bars, current densities from 0.6 to 1.6 amperes per cm.^{2} with an arc in a tube 0.75 centimetre in diameter. Within the relatively narrow ranges covered by these experiments, he was able to express his results for the pressure gradient by the empirical equation

$$\frac{dp}{dx} = C\,\frac{I\sqrt{M}}{p}\,\frac{dV}{dx} \tag{17}$$

where C is a constant, and I is the current density in the arc. Expressing p in bars, I in amps. cm.$^{-2}$, V in volts, x in cm., the value of the constant best fitting the results is $C = 77$.

Comparing Equations (15) and (17) we see that they are in many respects similar. If the two equations are to give the same value for $\frac{dp}{dx}$, we must have

$$\frac{I\sqrt{V_0}}{I_p} = 0.241\,\frac{\mathfrak{E}\lambda p}{r(1+\rho)} \tag{18}$$

The temperature of the gas in the tube may be assumed to be roughly 1000° K. The viscosities [12] of helium and argon at this temperature are given in Table II. The free path at the average pressure (900 bars) is calculated from the viscosity in the usual way. The quantity ρ is found from Equation (16). The values of

TABLE II.

Analysis of Rüttenauer's Data on the Pressure Effect.

Gas.	η	λp	λ/r	ρ	$\frac{I\sqrt{V_0}}{\mathfrak{E}I_p}$	$\sqrt{\frac{m_p}{m}}$
He	4.25×10^{-4}	115	0.34	0.10	67	86
A	5.6×10^{-4}	48	0.14	0.71	18	273

$I\sqrt{V_0}/(\varepsilon I_p)$ which have been calculated by Equation (18) are reasonable. The experiments with the mercury vapor arc give the ratio $I_e : I_p = 340 : 1$, but the true value may lie close to $605 : 1$, which is the square root of the ratio of the mass of the mercury ion to that of the electron. Because of elastic collisions between the electrons and the mercury atoms and the walls of the tube, the electron current density I_e is sometimes as much as twenty times as great as the apparent current density I in the arc. Therefore, in general, we may assume that I/I_p may be several times less than $\sqrt{m_p/m}$. The data of Table II show that the ratio of $\sqrt{m_p/m}$ to $I/\varepsilon I_p$ is equal to about 1.3 for helium and 1.5 for argon.

Rüttenauer finds that when the pressure is lowered, $\frac{dp}{dx}$ reaches a maximum and slowly decreases. An arc in argon with a current of 0.16 ampere in a tube 0.75 centimetre diameter gave a maximum pressure gradient of 1.86 bars per centimetre at $p = 600$ bars; 1.63 at 333; 1.30 at 133, and 0.97 at 75 bars. As the potential gradients were not recorded these data cannot be used directly to test the equations. It is clear, however, from Equation (15) that as the pressure decreases the gradient should increase about inversely proportional to the pressure until λ becomes about equal to the diameter of the tube. At lower pressures λ must be considered to remain approximately constant. The decrease in the gradient at still lower pressure is probably accounted for by the increase in V_0 as was found for the case of mercury (Table I).

SUMMARY.

In the positive column of the mercury arc the electrons have velocities distributed in accord with Maxwell's law, and the directions of motion are distributed nearly at random. The average velocity of the electrons is approximately independent of the arc current but depends on the pressure. The average kinetic energy of the electrons, expressed in terms of the corresponding voltage, is 3.9 volts at 1 bar pressure, 2.9 at 4.4 bars and 1.7 at 33 bars.

Isolated electrodes, or glass surfaces, in the uniformly ionized

gas of the arc, become charged 5 to 15 volts negatively with respect to the gas. The wall of the tube thus absorbs all positive ions moving towards it, but repels all but a minute fraction of the electrons, so that these act largely as if specularly reflected from the wall without loss of energy or momentum.

The impact of the positive ions on the wall causes a heating effect on the wall which ranges from 15 to 50 per cent. of the total energy in the positive column.

The momentum delivered to the wall by the ions is the probable cause of the pressure effect observed by Hamburger and Skaupy by which the pressure of the gas near the anode is greater than at the cathode. Equations are derived by which this pressure effect may be calculated. The results are in rough agreement with the meager experimental data available.

Two methods are described for measuring the space potential in ionized gases. The first consists in the use of a hot sounding electrode whose potential is adjusted until the electrons emitted by it are just able to escape. The second is based upon a kink observed in a semi-logarithmic plot of the current voltage curve of a cold sounding electrode, which occurs when the electrode reaches the same potential as the surrounding space.

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[12] Calculated from data in Kaye's and Laby's tables.

THE SCIENTIFIC APPLICATIONS OF RADIOTELEGRAPHY.*

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RADIOTELEGRAPHY is taking a more and more important place, not only among the various methods of transmission of human thought, but likewise among the processes of research and analysis, for which it can be employed to extend the field of scientific knowledge.

Its evolution and growth have been extraordinarily rapid. It was first applied to intercommunication between ships at sea and the shore. Later, its introduction, in competition with land and cable lines, was attempted. The first efforts in this direction presented many obstacles, because at that time the technic of the art was undeveloped, and it may be truly said that if radiotelegraphy had been invented first, wire telegraphy would have been considered an immense improvement. It was the persistent work of a great number of physicists and engineers that little by little brought about such advances in the art, that to-day radiotelegraphy may be regarded as a powerful rival to the cable system. These advances have even made it possible, within a short time, for Hertzian telegraphy to make an invasion in wired telegraphy's own domain, and already "wired wireless" has received important applications, of which the final development is still far off.

Radiotelephony, in the meantime, had come into being, but its development is still very slow because of its many defects. However, even telephony by wire has scarcely attained a satisfactory degree of refinement. Despite the serious difficulties which Hertzian telegraphy and telephony still encounter in these different spheres, their future is assured, for new discoveries are constantly yielding important improvements.

It was soon realized that the transmission of radiotelegraphic and radiotelephonic messages were not the only useful applications of Hertzian impulses. Another class of practical application was

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evolved for the transmission of special signals. For instance, radiogoniometry, telemechanics, the reproduction of drawings, the piloting of airships by Hertzian impulses transmitted on telegraphic lines, etc. Many achievements of this kind are on record and the future is equally very promising in this direction.

It became finally possible to apply Hertzian waves, and their special technic to the study of purely scientific problems, and even to the creation of new methods of research in various branches of science.

To begin with, may be mentioned the considerable services rendered by Hertzian technic in a great number of questions relating to "time." While moderately precise hourly radiotelegraphic signals are a great aid to navigators in determining their position at a given moment, hourly signals of very great precision, with the aid of astronomic observations, permit this determination with a degree of precision unobtainable by any other process, where the error is of the order of ten metres. It was by this means that the difference in longitude between the observatories of Paris and Washington was determined in 1913. A very great number of analogous determinations have been made in all parts of the world by this method which has now become classic.

Under the direction of a special committee appointed by the International Unions of Astronomy and Geodesy, an international operation of this kind is in progress. The object is a redetermination, by this method, in coöperation, of the principal geographic points of the world with the greatest degree of precision attainable. One of the projects in view consists in determining, first of all, the position of three equidistant points and situated approximately on the same parallel at some medium latitude, such as San Francisco, Algiers and Shanghai. The sum of the three differences of longitude between these successive pairs of points should be 360 degrees. The departure from this figure will determine the value of the precision actually obtained. Without entering into the details of the project, it is interesting to point out that in the operation, new processes and highly perfected apparatus will be employed, as well for the astronomical observations as for the radiotelegraphic operations. A first series of preliminary observations, with the object of checking the methods and calibrat-

ing apparatus, is likely to be made at the end of the present year or in 1924.

If the precision with which the relative positions determined is only a few metres, as it is hoped, it will be possible, in repeating the operations several years later, to be assured that these relative positions have not changed, taking into account the displacement of the pole. If otherwise, the difference observed would be attributable to a deformation of the earth's crust, and a methodical study of that subject might then be undertaken.

In operations of the kind just outlined, it is necessary to know as nearly exactly as possible, the velocity of propagation of Hertzian waves on the surface of the earth. Already it has been shown that this velocity differs very little from the velocity of light. New measurements are shortly to be undertaken to increase the precision of this determination. Will it be possible to devise a method by means of Hertzian waves, leading to a repetition of an experiment analogous to that of Michelson? That appears very difficult, but not absolutely impossible. With the Dufour cathodic oscillograph, it is possible to measure practically, on a photographic plate, intervals of time of the order of the twenty millionth of a second, perhaps even a hundred millionth, counted on the record made by Hertzian waves. It may be possible to devise a method of utilizing this marvelous apparatus for the problem in view.

Still on the subject of "time," we may again call attention to the value of Hertzian impulses in investigations on the variation of the intensity of gravity at a given station at different times or at several stations at the same instant. The process is in effect a comparison of the periods of free pendulums at these points, that is to say, a comparison of the number of oscillations of these pendulums during a given time. This comparison is easily effected by inscribing at each station on the same recorder the oscillations of the pendulum and two Hertzian signals at an interval of several minutes which appear at all the stations.

It has even been possible for Mr. H. Abraham to contrive, by means of three-electrode tubes (audions or triodes) used in wireless telegraphy, a kind of clock which is entirely electric and devoid of any mechanical element, capable of producing electric "ticks" of extremely short duration at rigorously equal intervals and adjustable at will. By means of such "ticks"

the intervals of time, measured from any origin, registered in the determinations above mentioned, can be subdivided with all necessary precision. Perhaps we may contemplate, in the not too distant future, the employment of these electric clocks in place of the astronomical clocks now used, for these would not be subject, like the latter, to errors and variations due to mechanical causes, seismological, *et cetera*.

Astronomy is even further indebted to the development of Hertzian science. In judiciously combining radiotelegraphic amplifiers with potassium photo-electric cells, it is possible to record luminous signals in the same manner as electric signals. The measurement of the luminosity of stars can then be realized. For example, by simultaneously recording the trajectory of a star in the field of an equatorial telescope and the beats of the astronomical clock, it may perhaps be possible, during the time, to determine precisely the position from the points of the curve which correspond to the passages of the star behind the wires of the reticule. The personal influence of the observer will thus be eliminated and with it a serious source of error. This combination of photo-electric cells and radiotelegraphic apparatus will certainly develop many scientific and practical applications. Will it perhaps lead to a solution of the problem of electrical vision at a distance?

The phenomena of the propagation of waves in air, in water, in the ground, considered either separately or simultaneously with material vibratory movements, have also either made possible or indicated interesting solutions of a variety of problems. In effecting, for example, by means of radiotelegraphic devices, vibratory movements of high frequency, Mr. Langevin has succeeded in producing under water, ultra-audible pencils of rays which could be directed at will and which were reflected from objects in their path. A method of making soundings at sea of very great precision is a notable application of this phenomenon.

It may incidentally be mentioned that it has likewise been possible to measure the velocity of sound in water with very great precision, by the following method: An explosion in the water and a Hertzian signal are simultaneously produced at a given station. At another station, a microphone receives the sound impulse and an antenna the Hertzian signal. Both impulses are

recorded on the same chronograph and the difference of time indicated determines the velocity.

Other investigations are in progress for applying the propagation of high-frequency oscillations to the study of the nature and disposition of geological strata. Already interesting results have been obtained.

The propagation of Hertzian waves through the air is affected by a multiplicity of phenomena and the study of their anomalies has already resulted in much work in the analysis of certain of these phenomena which still remain puzzling enough. A notable one of these is that the energy proceeding from a given emission and received at some other point varies within very wide limits, with different days and with different hours of the day. The influence of the seasons and of solar light has also been definitely established. Moreover, when an emission is observed by means of a radiogoniometer, the direction indicated by this apparatus is not constant; it varies according to the hour of the day, and in a different manner in the various seasons, and particularly during the night. It has also been noticed that the variations observed from the same emission are not alike when the operators occupy different positions; they are likewise a function of the wave-length employed in the emission. Finally, atmospheric electric phenomena, as well as other not easily defined causes, introduce disturbances of reception by the superposition of these transient signals upon the normal radiotelegraphic signals. A critical study of all these facts has been in progress for several years, notably by Mr. Austin in the United States, by Messrs. Jouaust, Mesny and others in France, England and Italy. Numerous observations have been made each day, curves have been plotted, but no law applicable to all the facts has yet been disclosed.

Some generalizations, however, appear warranted at the present moment. For what applies to the mean value of the energy proceeding from a given discharge and received at a station, the Austin-Cohen formulas agree best with the actual results. On the other hand, the theoretic formulas by such mathematicians as Henri Poincaré, Macdonald, Nicholson, in the derivation of which they uniformly took into account the diffraction of the waves on the surface of the terrestrial sphere, did not account for the very considerable increase in range obtained in telegraphic transmission. Quite recently Mr. Watson has shown that in admitting, within

the limit of the atmospheric height of one hundred kilometres, the existence of a conducting stratum and consequently capable of reflecting the waves, the theoretic formula becomes identical with the Austin-Cohen formula. The existence of this stratum, the Heaviside layer, appears, moreover, to be justified by numerous considerations relating to astronomical physics. However, the Austin-Cohen formula only agrees with actual results with a rather wide approximation. It still remains to explain the variations of intensity of reception at the various hours of the day, radiometric deviations, . . .

Thus, the conclusion has been reached that the surface of the Heaviside layer was irregular, that certain phenomena of ionization which occurred beneath this layer in the upper atmosphere affected the propagation of the waves. Perhaps, indeed, it will be necessary to consider phenomena in even lower strata of the atmospheric layer. All this is still quite vague, but it can be scarcely otherwise, because we are unacquainted with nearly all the meteorologic and electric phenomena of the atmosphere. The numerous observations which are being made on the intensity and direction of radiotelegraphic reception will probably enable us to penetrate little by little into the mysteries of these phenomena. The waves which are observed, in effect, traverse all atmospheric regions situated between the points of emission and reception and consequently can throw light on the states of these regions. Meteorological stations are all keenly interested in these investigations and lend a most valued coöperation to radiographic physicists.

By the employment of very short waves, American and European radio amateurs have recently carried on with success some experiments in transatlantic communication, with apparatus of very low power. Numerous radio messages by telegraphy, and even by telephony, were obtained from both shores across the ocean. What path did these waves follow? Did they glide along the surface of the sea, or were they reflected by the Heaviside layer? It is yet impossible to conclude definitely. The very great irregularity of reception is not conducive to a ready solution; it demonstrates, however, that the atmosphere plays a dominant rôle in this matter. Special investigations are now in progress in France with a view to adding a new contribution to this research. By means of special antennæ, producing an adjustable directive

radiation, very short waves are transmitted on days and at hours announced in advance. Observations are made at various distances and already very interesting results have been obtained, notwithstanding that they are still insufficient to permit conclusions to be drawn from them.

Researches relating to the electric disturbances which affect receivers are likewise being carried on assiduously. Important observations have already been made, notably by Mr. Austin, concerning the direction of the source of these disturbances, but our knowledge on the subject of their nature and their various causes is still very imperfect. Researches and special experiments on these various questions have been undertaken by L'Union Internationale de Radiotélégraphie Scientifique, and it is to be hoped that in a few years it will be able to report substantial results.

In a different field, the development of Hertzian technic has considerably improved the precision and increased the variety of methods of electric measurements: Capacitance, inductance, resistance, specific inductive capacity, etc. The measurements of frequency, electromotive force, phase, etc., have equally been carried to a degree of precision previously unattainable. With respect to measurements of frequency, it is likewise notable that it will shortly be possible to control the frequency of a transmitter by means of the standard apparatus itself. This prospect will insure the attainment, on questions of frequency employed in practice, of an agreement very difficult to attain with other physical magnitudes.

It has been possible to extend the study of the magnetic properties of iron by making use of currents of very high and adjustable frequency, and by employing the devices of radiotelegraphic technic. The application of waves of very short length may possibly lead to a determination of the periods of vibration of atoms. The application of amplifiers has already made it possible to determine the appreciable time occupied by the molecules of iron in acquiring magnetization. It is also with this apparatus that Mr. Hollweck has rendered audible the emission of alpha particles. Measurements of the terrestrial magnetic field, moreover, can very easily be made by means of a new method evolved by Mr. Perot which again admits the employment of certain apparatus utilized in radiotelegraphy.

Even in medicine the progress of Hertzian technic has found very useful applications.

With electric furnaces, designed in accordance with the same principles, enormous temperatures have been realized which had never been obtained by previous processes.

It would be possible to cite many other researches and scientific work undertaken, in which either radiotelegraphy itself or methods and apparatus evolved for it are utilized. It is hence obvious that there is a boundless future for the applications of Hertzian waves and that it is to the greatest advantage of all physicists, whatever their specialty, to keep in close touch and coöperate in the development of this branch of science.

Antifriction Effect of Grooves in Bearings.—The settlement of the long-vexed question, grooves in bearings for efficient lubrication, may now be regarded as reached. Dr. T. E. Stanton, F.R.S., D.Sc., Director of the National Physical Laboratory, England, has just reported the result of his painstaking researches in a lecture, "The Nature of Lubrication in Engineering Practice," to the International Air Congress in London.

Doctor Stanton states as a result of his research that: "Using an ungrooved journal and an ungrooved bearing, with castor oil as the lubricant, it was found that steady conditions could be obtained, but that the coefficient of friction was 15 per cent. higher than with the grooved surfaces and that substituting a grooved journal for the plain one did not improve matters. In the case of the Bayonne oil the increase in friction due to using ungrooved surfaces was 22 per cent.

"It is clear, therefore, that a system of grooving is essential in order to obtain the minimum friction due to the materials of the surfaces and lubricant employed."

Particular stress was laid on the value of adding small quantities of organic acid to mineral lubricating oils, on which phase of the question *The Engineer* of London comments: "The insufficiency of the Reynolds theory is, however, in our opinion, presented by the known effect of adding small quantities of fatty acid to mineral lubricating oils. According to the hydro-dynamical view, the nature of the lubricant is immaterial, its viscosity alone affecting the result. Yet to take some figures recorded by Doctor Stanton, figures which are amply borne out by practical experience, the addition of 1 per cent. of organic acid to Bayonne oil, an amount quite insufficient to have any noticeable effect on the viscosity, reduced the coefficient of friction in a bearing by no less than 17 per cent." H. L.

EFFECT OF THE GAUZE IN THE FRANCK MODIFICATION OF THE RUTHERFORD ALTERNATING CURRENT METHOD FOR MEASURING IONIC MOBILITIES.*

BY

LEONARD B. LOEB, Ph.D.

National Research Fellowship, University of Chicago.

In a previous paper[1] it was shown that the apparent mobility of the negative ions, as given by the Franck modification of the Rutherford alternating current method, varied through large limits as the auxiliary field strength G was varied. It was further shown that the magnitude of this effect indicated rather an instrumental effect of the gauze than a change in the nature of the ion with time. It is the purpose of this paper to show just how this instrumental effect of the gauze must change the value of the mobility found by its use. An extensive series of measurements was made on the mobilities of the ions changing the values of the auxiliary field G (Fig. 4), the value of the alternating field at which the ions just cross E_0, and the frequency of the alternating field, but maintaining all the other conditions the same. The gauze used was a perforated sheet brass .035 cm. in thickness and 10 cm. in diameter with 9 holes of 2.3 mm. diameter per square cm. Its distance from the plate p was 1.29 cm. and its distance from e was 1.42 cm. The frequencies used lay between 15 alternations and 75 alternations per second. The results obtained may be summarized as follows:

1. For $E_0/G = A$ less than unity the mobility of the ions lies above 2.15 cm./sec. and increases slowly as A is decreased to a value of 2.35 cm./sec. at $A = .08$.

2. For A greater than unity the mobility lies below 2.15 and decreases almost linearly as $\log_{10} A$ increases down to a value of 1.66 at $A = 55.0$.

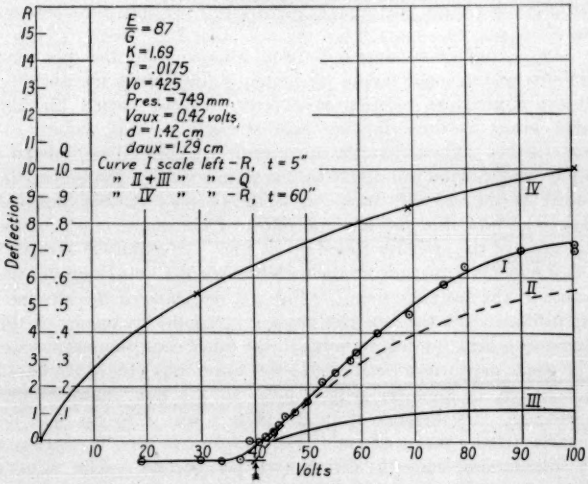
3. At values of A about unity the mobility curves make sharp intercepts with the voltage axis. As A decreases they remain fairly well defined except at the lowest values of A used, where

* Communicated by Dr. W. F. G. Swann, Associate Editor of this JOURNAL.

there is a distinct tendency for these intercepts to develop asymptotic feet. As A increases the intercepts become rapidly more and more rounded until at the point where $A = 55$ it becomes almost impossible to pick a definite intercept of the mobility curve with the axis (Figs. 1, 2 and 3, curves I).

4. For high values of G the current does not fall to 0 below E_0, the critical value of the alternating field, but attains a constant

FIG. 1.



value equal to the current observed when E is 0 (Fig. 3). The magnitude of this current increases as G increases.

5. For lower values of G the ion current falls to 0 below E_0 and remains there (Fig. 2). At the lowest values of G the current below E_0 reverses in sign and increases in magnitude as G decreases (Fig. 1). The reversed current is in all cases small compared to the currents in the opposite direction observed with a large G.

6. If it be assumed that the ions have a unique mobility K and that all the ions start at the level of the gauze, *i.e.*, at a plane d cm. from the electrometer plate e, then the ions will reach the

upper plate in the time t if $t > d/EK$. If we designate the maximum possible current to the electrometer plate at a fixed field strength E as I_0, then in a time dt the electrometer receives a charge $dq = I_0 dt$. For a square wave alternating field of strength E the ions can only cross during a time interval whose length extends from $t - d/EK$ to $t - T$, the time of an alternation, hence the quantity received by the electrometer in one alternation (*i.e.*, in a time T) is given by

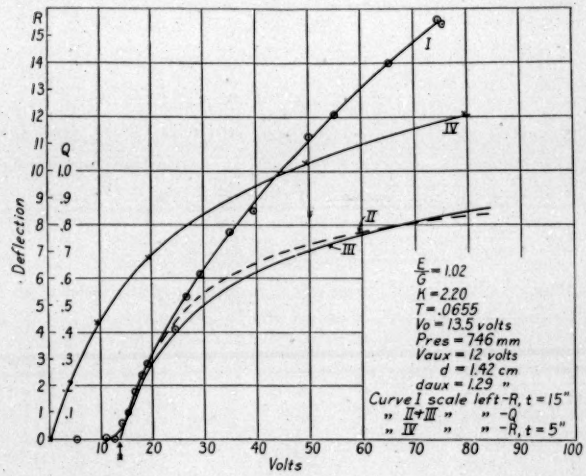
$$Q = I_0 \int_{d/EK}^{T} dt = I_0 (T - d/EK)$$

Q can also be considered as the quantity delivered by an average current I, in a time T, hence

$Q = IT = I_0(T - d/EK)$ or $I/I_0 = 1 - d/(TKE)$. But $d/KT = E_0$ where E_0 is the critical field strength for which ions can just cross the plates whence $I/I_0 = \frac{E - E_0}{E}$. Now experimentally I is nothing but the electrometer reading at the alternating field strength E, and I_0 is one-half the maximum deflection possible for a field strength E when there is no alternating field, *i.e.*, it is the value of the saturation current. The reason that I_0 is one-half the maximum deflection with the fixed field, is that with the alternating field the ions are driven across the plate for but half the time, that they are with the fixed field owing to the reversal of the field. Now it was found on comparing the computed and observed I/I_0 curves for different values of A, that for values of A greater than unity the observed curves fell markedly below the computed ones, while for values of A below unity the two curves coincided in a satisfactory manner except for the lowest values attained where the observed curves rose very slightly above the computed ones. This is well shown in Figs. 1, 2 and 3 for values of A equal to 87, 1.0 and .068, respectively. (In these figures curve III is the observed $\frac{I}{I_0}$ curve, curve II the computed one and I gives I while IV is the saturation curve.) In the extreme case of $A = 87$ the observed I/I_0 is only one-third the computed curve. This can mean only one thing under these circumstances and that is that with the relatively high alternating field only a fraction of the ions that are available reach the field E, and hence the upper plate.

To explain all these effects one need merely assume that a phenomenon occurs which has been found to occur in the use of gauzes or grids in other experiments, *viz.*, the penetration of fields through the gauze. It has been shown by Van der Bijl [2] and others that when we have a field G produced below a gauze as in Fig. 4*a*, it penetrates through the gauze to a slight extent, so that the field in the space labelled E above the gauze has no longer the value E indicated by the potential difference imposed upon

FIG. 2.



g and e, but attains a value $E + G/m$, where m is a quantity greater than unity and called by Van der Bijl the amplifying factor. The condition represented in Fig. 4*a* is the condition existing when the gauze g is in the negative phase of the alternating potential, *i.e.*, when ions are being driven to the electrometer plate E. When the field reverses in E, as in Fig. 4*b*, then the field G still attempts to penetrate the gauze in the same sense as before. However, the field in E also acts to penetrate the gauze in the opposing sense. The resulting field will be determined by the relative strengths of the fields G and E.

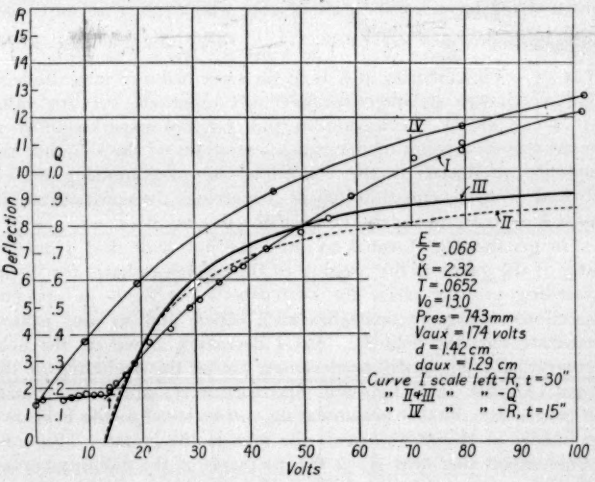
Let us assume that $A = \frac{E_0}{G}$ is less than unity. Then the field driving the ions to the electrometer plate e is actually $E + G/m$, while in computing the mobility the field is assumed to be E. Thus since K is taken as d/ET, K will appear larger than it really is. In fact K', the erroneous value of the mobility, will be related to K the true value, by $K'/K = \frac{d/E_0T}{d/\left(E_0 + \frac{G}{m}\right)T} = 1 + 1/Am$. If the quantity m† has a value of about 200, which is not an unreasonable assumption, $K'/K = 1 + \frac{1}{.07 \times 200} = 1.07$ for the case where A is .07. This increase in K is of the same order of magnitude as that which was actually experimentally observed, for this value of A. A closer verification of this relation experimentally is impossible on account of the erratic variations of the values of the mobility produced by the conditions of measurement. It is obvious from the equation that as A increases the apparent mobility will decrease to nearly the normal value at $A = 1$.

In general for A equal to unity the ions will start from the level of the gauze at the opening of the negative phase, for in the preceding positive phase the two penetrating fields in opposite directions essentially neutralize each other, and so ions cannot penetrate into the field E. As A decreases, however, the field penetrating from G will predominate and at the beginning of the negative phase some ions will find themselves above the gauze. In general the number accumulating will be small as the fields are so intense as to carry most of the ions to the gauze. Thus one would expect that near $A = 1$ the intercepts of the mobility curves would be sharp and the theoretical I/I_0 curves would coincide with the computed ones (curves II and III, Fig. 2). For very low values of A the ions would not start at the level of the gauze but slightly above it, and this small accumulation of ions above the gauze would contribute more to the current than theory calls for, since they enter the space before the negative phase begins. Thus the observed I/I_0 values would

† An attempt at the direct evaluation of m for the conditions of these measurements was made and gave $m = 130$. This can, however, only be taken as the lower limit for m as the value is exceptionally sensitive to improper electrostatic shielding and it is almost impossible to decide when this has been achieved.

be slightly greater than the computed ones (curves II and III, Fig. 3). The intercepts of the mobility curves would also tend to become less definite because of the indefinite level from which such accumulated ions start. As can be seen in Fig. 3, this actually occurs. Finally, if the field E be made 0, since the penetration of the field G gives an effective field G/m between g and e, there should be an appreciable current to the electrometer

FIG. 3.

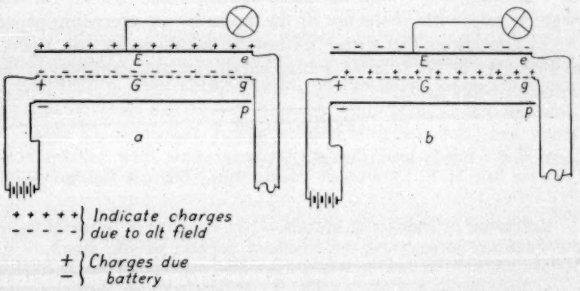


due to this field. The existence of the penetrating field is definitely shown by the constant electrometer current below the critical value E_0 (Fig. 3). The magnitude of this current is about that which would be expected from a field of $G/100$ volts/cm.

Let us now take A greater than unity. Under these circumstances the effect of $G/200$ on E in the negative phase becomes entirely negligible. During the positive phase of E, however, the field E/m penetrating the gauze in a sense opposite to G becomes appreciable. In the case where $A = 55$, E/m becomes about 0.3 volt per cm., while the value of G is actually but 1.16 volts/cm. Thus, in the neighborhood of the meshes, the ions encounter a

retarding field which keeps them from entering E. As a result of this the ions are driven by the opposing fields to the metal gauze where they are lost. Accordingly, at the beginning of the negative phase there is below each mesh of the gauze a small space, which might achieve a depth of 2 mm., in which no ions are to be found, and the depth of this space will increase as A increases. Thus an appreciable period will elapse before the ions are driven across the space into the field in E, with the weak field existing in G. This delay will act to shorten the effective value of T the time of action of the alternating potential, a stronger E_0 will be required to force them across in this time, and hence the value of the mobility will

FIG. 4.



appear too low. An exact evaluation of the magnitude of this effect is not easily accomplished. The production of these ionless pockets below the meshes of the gauze will have for a result that the starting level of the ions at the initiation of the negative phase will be far less clearly defined than before, so that the mobility curves should develop markedly asymptotic intercepts with the voltage axis as A increases (Fig. 1). The loss of the ions from the region of the pockets will also have the effect of reducing the total number of ions available for the electrometer current. Thus the observed I/I_0 curves should fall below the computed curves, as is actually seen to be the case in curves II and III, Fig. 1. Finally, if the field due to E during the negative phase is great enough it may succeed in pulling a few positive ions from the space C during this phase and hence produce a reversal of the current. This would become manifest especially below E_0 where no nega-

tive ions were crossing, since the positive phase of E was always greater than the negative phase by about 10 per cent.

It is therefore seen that all the phenomena connected with the change in K produced by varying the auxiliary field can be satisfactorily accounted for by the penetration of the fields through the gauze, so that no necessity arises for calling upon vague speculations as to ion formation to account for the phenomena. It may be pointed out that when the value of A approaches unity the conditions are essentially fulfilled for determining the true value of the mobility of the negative ions, for under these circumstances the computed and observed I/I_0 curves coincide. The value of the negative ion mobility obtained at this point lies close to 2.20 cm./sec., which agrees with the value found for the negative ions without the use of the gauze in the preceding paper.

In conclusion the writer wishes to acknowledge his thanks to Prof. W. F. G. Swann for his kind advice and criticism in the writing of this paper.

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[1] LOEB, L. B.: This JOURNAL, October, 1923, p. 537.
[2] VAN DER BIJL, H. J.: "Thermionic Vacuum Tube," McGraw Hill, 1920.

Corrosion of Industrial Metals.—In a conference of members of the Faraday Society and the Sheffield Section of the Institute of Metals much information was presented concerning the corrosion of common metals and alloys. Dr. D. W. Hatfield, of Sheffield, gave a summary of his experiments and observations on the corrosion of industrial metals, including forms of iron and steel, silicon iron, aluminum, duralumin, and several kinds of bronzes. Tests were made with mineral and vegetable acids, fresh and sea water and some common salts. Contrary to what might be expected from the electrochemical theory, some of the heterogeneous alloys, such as nichrome, stainless steel and silicon iron, showed the most resistance. Aluminum and monel metal show resistance, but Doctor Hatfield regards them as essentially heterogeneous owing to impurities. Steel containing 14 per cent. of manganese is very soluble in acids, and is also subject to general corrosion. As a result of extended experiment, Doctor Hatfield is led to the following views: Alloys and steels are now available that effectively resist corroding influences. Actual test representing the conditions to which the material is to be exposed must be made in each case. No law is yet elucidated which enables the metallurgist to foretell the action of a given corrosive agent on a given metal or alloy. In the paper, considerable attention is given to the physical chemistry of the subject. H. L.

STUDIES IN PHOTOGRAPHIC SENSITIVITY.*

III.

TOPOCHEMISTRY OF DEVELOPMENT AND SENSITIZING NUCLEI.

BY

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Research Laboratory of the Eastman Kodak Company.

VIII. DESTRUCTION AND REGENERATION OF LATENT IMAGE AND THE EFFECT OF KI.

1. *Physical Development before Fixation and Chemical Development.*—We now proceed to the action of potassium iodide, in conjunction with chromic acid, on the *latent image,* both for physical development before fixation, and chemical development. In Table IX (see this JOURNAL, preceding number) are given some results with quite weak CrO_3 solutions, and 1 per cent. iodide. From these it appears:

(*a*) With physical development of Graflex emulsion only 16° C.J. were obtained, as against 25° by chemical development.[44] But, using a bath of 1 per cent. iodide after exposure, with 5 per cent. Na_2SO_3 (to reduce oxidation, according to Lüppo-Cramer) 22° C.J. were obtained by physical development, 23° C.J. by chemical. This is a much closer approximation, and agrees with Lüppo-Cramer's results on the favoring influence of KI on physical development. But, before the whole of this be attributed to "nucleus exposure," note from Table IX, experiments 529–530, that on soaking in plain water before physical development, 20° C.J. are obtained instead of 16°. This difference between "dry" and "wet" plates was repeatedly confirmed, and shows that part only of the iodide effect is to be attributed to the iodide itself. Experiment 489,

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[44] Chapman-Jones values are only relative and not absolute.

Table IX, shows that quite dilute chromic acid after iodide cut back the scale to 15° for physical, but practically did not affect it for chemical development. This discrepancy again is not easy to account for on the "nucleus exposure" hypothesis as the results in the table show, the effect with physical development is lessened when there is Na_2SO_3 present with the KI. (*Cf.* also experiments 490 and 517.) The results with .05 per cent. CrO_3 are not very conclusive, and some further tests were made with .2 per cent. CrO_3. Experiments 521 and 522 show that a repetition of $CrO_3 \longrightarrow KI$ and of $KI \longrightarrow CrO_3$ treatment gave very similar results for physical development. The image was not completely destroyed. This may be a question both of size of grain and thickness of emulsion layer. The experiments 525, 526, 508, 518 with CrO_3 alone, followed by Na_2SO_4 pickle, are not very concordant, which may be partly due to the circumstances already noted, but possibly also to the uncertainty of elimination of CrO_3 with the sulphate pickling bath.

(*b*) In regard to *chemical development,* experiments 503, 509, 510, 511, 512, the .05 per cent. CrO_3, used for short times, was evidently little effective, but .20 per cent. lowered the scale from 25° to about 15° with iodide, to 19° without. Here again, the order $CrO_3 \longrightarrow KI$ or $KI \longrightarrow CrO_3$ gave much the same result.

Applying the same treatment to lantern slide emulsion, Table X shows the results in part. The experiments are not quite comparable with the Graflex ones, but indicate a lower resistance of the latent image. Experiment 419 showed a definite "revival" of the latent image for physical development, after destruction by CrO_3, by use of .34 per cent. KI. With .05 per cent. CrO_3 and *chemical* development, inconclusive results were obtained, since, though plain CrO_3 gave loss of scale, .34 per cent. iodide *followed* by CrO_3 gave no loss, nor .34 per cent. iodide alone. Yet on the disinterment theory, the iodide pretreatment should have led to nearly total destruction. In one case of repeated $CrO_3 \longrightarrow KI \longrightarrow CrO_3$ treatment, reduction to 16° C.J. was effected, but this was not confirmed by the check experiment, which showed only slight loss of density.

These results require further work with higher CrO_3 strengths.

TABLE X.

Action of CrO_3 and KI on Latent Image. Seed Lantern Slide; Exposure 16 min. at 25 cm. From 5-volt lamp.

Expt.	Treatment. 1	2	3	4	Result in Degrees C. J. Phys. Develop.	Chem. Develop.
414	Nil				>25	
415	0.5% CrO_3, 0.12% H_2SO_4, 5 min.	3 washes	0.17% KI, 2 min.	Wash	0*	
416	0.5% CrO_3, 0.12% H_2SO_4, 5 min.	3 washes	Wash		0	
	Exposure 4 min.					
417	Nil				23	
418	As in 415	3 washes			0	
419	As in 415	3 washes	0.34% KI, 2 min.		19	
420	As in 415	3 washes	5% Na_2SO_3, 2 min.		0	
	Exposure 160 sec.					
421	Nil					25
422	0.34% KI	Wash				25
423	0.34% KI	0.05% CrO_3, 5 min.				
424	0.05% CrO_3	Wash				20
	Exposure 3 min.					
648	Wash 15 min.				24+	
649	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash			0	
650	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash	0.17% KI, 2 min.	Wash 15 min.	13	
651	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash	0.34% KI, 2 min.	Wash 15 min.	22	
652	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash	1.0% KI, 2 min.	Wash 15 min.	20	

*Experiment 415 is not in agreement with experiments 419, 650, 651, 652, and 659, and appears to be an error in recording the experimental work or in the work itself.

TABLE X.—*Continued.*

Action of CrO_3 and KI on Latent Image. Seed Lantern Slide; Exposure 3 min. at 25 cm.

Expt.	Treatment. 1	2	3	4	Result in Degrees C. J. Phys. Develop.	Chem. Develop.
653	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash	0.34% KI	Repeated 1, 2, 3 and then wash 15 min.	0	
654	0.34% KI, 5% Na_2SO_3	Wash 15 min.			24+	
655	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash 15 min.	0.34% KI, 5% Na_2SO_3	Wash 15 min. and then repeat 1 and wash again 15 min.	0	
657	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash 15 min.	5% $NaHSO_3$, 10 min.	Wash 15 min.	0	
658	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash 15 min.	5% Na_2SO_3	Wash 15 min.	0	
659	0.5% CrO_3, 0.1% H_2SO_4, 5 min.	Wash 15 min.	1% KI, 5% Na_2SO_3	Wash 15 min.	20	

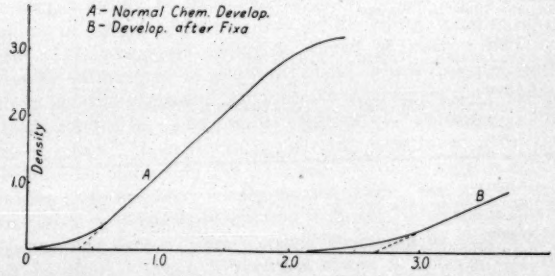
But they show that the effect of iodide in conjunction with oxidizers destroying the latent image is not as simple as represented by Lüppo-Cramer. On the other hand, the results with physical development, before fixation, on lantern plates (Table X) and with .5 per cent. chromic acid, are in good agreement with Lüppo-Cramer's theory. Regeneration, or "disinterment" of occluded latent image, after destruction of the "soluble" latent image with .5 per cent. CrO_3 is shown in experiments 649, 651, 652. A further treatment with CrO_3 destroys this, and still further treatment with KI is ineffective, as would be expected.

Part of the iodide effect here may be attributed to the increased adsorption by Ag-ions from the acid silver developer making a smaller, reduced nucleus more effective. Parallel experiments, so far as possible, with chemical development, are in hand, and should show whether the "disinterment" hypothesis is confirmed by this.

2. *Physical Development after Fixation.*—If the superficial

"latent image" be removed by chromic acid, the "occluded" image set free or disinterred by iodide, and this then removed by chromic acid, there should remain very little for development after fixation. Some preliminary experiments with lantern emulsion showed some reduction by such multiple treatment, but the chromic acid used was only .05 per cent. and the experiments will be extended with stronger solutions. As illustrating the range of "latent images" already referred to (p. 661 of previous paper), it required an exposure of 1920 seconds to give the

FIG. 2.



same "Schwellenwert" for development after fixation as 40 seconds did for normal chemical development. The comparison is illustrated by the characteristic curves in Fig. 2.

It is to be noted that in these experiments concentrations of KI of the order found effective in accelerating development with low potential developers[45] (Lainer effect) were used. *As a general result, such concentrations of iodide had little or no effect upon the action of oxidizing agents.* While the former is most effective at concentrations of the order of .002 to .02 per cent., the latter requires concentrations of the order .2 to 2 per cent. As we shall show later, the physical disintegration, and increase of surface, produced by the action of iodide on the original AgBr grain, increases very rapidly up to 1 per cent. KI.

So far as the effect of persulphate on the latent image and sensitivity is concerned, it appeared less effective, and much less reproducible, than chromic acid. Experiments made with 5 per

[45] *Cf.* Sheppard and Meyer, *loc. cit.*

TABLE XI.

Action of Persulphate on Latent Image (a) and on Sensitivity (b). Seed Graflex Plate.

Expt.	Treatment. 1	2	3	4	Chemical Development Results in C. J. (a)	(b)
109	Nil				24–5	24–5
121						
110	2% $Am_2S_2O_8$	Washed				15
122	0.5% H_2SO_4 5 min.					
111	2% $Am_2S_2O_8$	Washed			20	
123	0.5% H_2SO_4 5 min.					
113	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed	5% Na_2SO_3	Washed		20
114	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed	5% Na_2SO_3	Washed	21	
124	2% $Am_2S_2O_8$ 0.5 % H_2SO_4 5 min.	1% Na_2SO_3	Washed			15
125	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	1% Na_2SO_3	Washed		23	
139	5% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed				14
140	5% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed			15	
141	5% $Am_2S_2O_8$ 1% H_2SO_4 5 min.	Washed				15
142	5% $Am_2S_2O_8$ 1% H_2SO_4 5 min.	Washed			15	
144	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed			17	
145	N/5000 KI 2 min.	Washed	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed	19	
146	N/5000 KI 2 min.	Washed	2% $Am_2S_2O_8$ 0.5% H_2SO_4 5 min.	Washed		15

cent. solution to find if prolongation over 10 minutes of the persulphate bath had any marked effect, showed no increased effect up to 140 minutes. A fogging action on unexposed halide, as previously recorded by Lüppo-Cramer, was frequently observed.

Experiments with a silver chloride emulsion showed a much greater resistance of the *latent image* to persulphate than the bromo-iodide emulsion. As in the case of chromic acid, the reduction of *sensitivity* by persulphate could be completely annulled by a bisulphite bath; both bisulphite, and still more neutral sulphite, producing increase on sensitivity.

IX. ON THE CONTINUITY OF SENSITIVITY, THE LATENT IMAGE, THE SOLARIZED LATENT IMAGE, AND THE VISIBLE IMAGE.

The great differences in behavior which naturally distinguish these phases of the photographic material (or better, define them) can very probably be explained in terms of the topochemical relations of colloid silver to grains of the silver halides, AgCl, AgBr, AgI, and their mixtures. Some reservation may be necessary with regard to sensitivity itself, which may not enter entirely into this category,[46] but with the other stages the evidence is fairly conclusive. The parallel behavior of "sensitivity" and "latent image" to oxidizers has already been noted here; the possibility of converting the solarized (reversing) plate into a sensitive plate has been frequently discussed. The use of oxidizers, such as persulphate, chromic acid, etc., in effecting this[47] indicates that excess "free" colloid silver can be removed by such oxidizers. Since a *reversed* image is obtained on re-exposure and development, the "occluded" image must still be affecting the process. On the other hand, after-treatment by such oxidizers, and development, without intermediate re-exposure to light, a *normal* image can be obtained, although development is very slow. We shall return to these "reversal" effects in a later communication, but may note here that Lüppo-Cramer[48] finds that a treatment with persulphate or chromic acid, which has the above-mentioned effect on the reactions of the solarized image, had no effect on the visible image, on such solarized plates. In partial agreement with this we found that impregnation of a Graflex plate with 1 per cent. CrO_3 did not affect appreciably

[46] The idea of sensitizers raises the issue whether they act by a preliminary formation of a trace of colloid silver, or whether the sensitizer and silver halide form a complex which is affected by light, *e.g.*, with reduction of the silver halide.

[47] Sterry, Lüppo-Cramer, Vidal, *et. al.* *Cf.* Lüppo-Cramer, *Photo. Prob.*, 1907, p. 112, **147**, 190.

[48] *Phot. Korresp.*, 1902, p. 694; *cf.* also J. M. Eder, *ibid.*, p. 648.

the production of a visible image. Further, the action of 6 per cent. chromic acid in bleaching out the visible image was very slight on fast, coarse-grained emulsions. On others it was variable, depending upon *both* grain size and the composition, *i.e.*, proportions of iodide, bromide, and chloride (*cf.* Table XII).

TABLE XII.

Emulsion.	Composition.	Scale Reduction of Visible Image.		Color Change.
D. O. P. Paper	AgCl	18	12	Pink → Mauve
D. O. P. Papers	AgCl / AgBr	18	10	
Bromide	AgBr	18	0	Pink White
Lantern	AgBr	18	10	Blue → Mauve
High Speed	AgBr / AgI	18	18	Purple / gray → Gray

These observations are noted for the sake of completeness, since they indicate the relative importance of the topochemical factor along the whole series of photographic phenomena.

Although straight chloride emulsions give high resistance, increase of bromide reduces it. But with a coarser grain, the bromide emulsions acquire a higher resistance again.

In general, our work fully confirms Lüppo-Cramer's general thesis of "facilitation of formation of free silver nuclei [germs] in consequence of the *presence* of silver iodide." We suggest that the reason for this lies in the lattice structure (arrangement of the atoms) of silver bromide and silver iodide, respectively. AgBr has a simple cubic structure,[49] of open type, in which solid solution of silver could occur relatively easily, *i.e.*, in terms of metallographic analysis, it is a good "host" to silver.[50] On the other hand, silver iodide forms naturally at these temperatures, a tetrahedral lattice of much more compact form, so that solid solution of silver would be precluded. It is this difference, we believe, together with the high adsorption of silver *ions*, etc., to silver iodide, rather than mechanical denudation which explains most of the remarkable iodide effects. Freshly formed silver—by exposure to light, or by development—is forced to orient itself differently, according as iodide is present or not.[51]

[49] R. B. Wilsey, *Phil. Mag.*, **42**, 262 (1921).

[50] *Cf.* W. Rosenhain, *Chem. Met. Eng.*, 1923, p. 442.

[51] *Cf.* S. E. Sheppard, "Action of Soluble Iodides, Etc.," *loc. cit.*

X. THE INFLUENCE OF OXIDIZERS ON THE SENSITIVITY, WITH ONE-GRAIN LAYERS.

In one-grain layers diffusion and strato-chemical effects are reduced to a minimum and may be regarded usually as negligible. The plates were prepared by a method already described by us.[52]

FIG. 3.

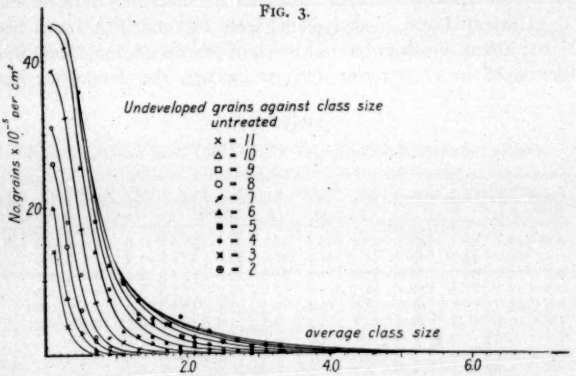
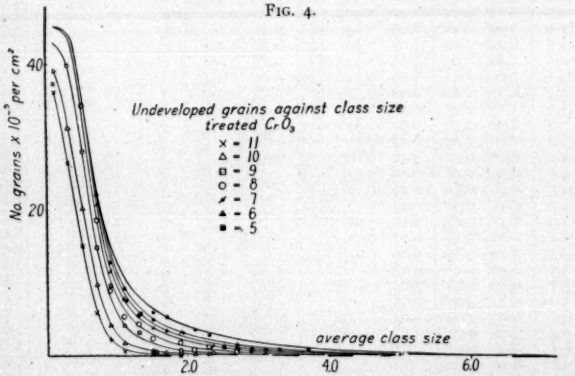


FIG. 4.



[52] *J. Phys. Chem.*, **27**, 1 (1923).

1. *Relation of CrO_3 Desensitizing to Size of Grain.*—Using a Seed Graflex emulsion coated in one-grain layers, plates were desensitized with 0.5 per cent. CrO_3 (+ .2 per cent. H_2SO_4), washed with 1 per cent. $NaHCO_3$ to help remove CrO_3, then with 1 per cent. HCl aq. to neutralize, then in several changes of distilled water.

Untreated and treated plates were exposed in a Jones non-intermittent sensitometer (11 steps in powers of 2). They were developed in 1/10 molar ferrous oxalate, the developed silver

TABLE XIII.

Graflex Untreated. Residual Grains $\times 10^{-5}$ */ cm.*^{2} *From Smoothed Curves.*

Class Size.	Original—Fog.	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
0.11	45.1	45.1	45.1	45.1	45.1	45.1	44.7	38.6	31.0	26.0	19.8	14.1
0.3	44.2	44.2	44.2	44.2	44.2	44.2	42.0	32.2	21.2	14.1	7.8	3.8
0.5	34.9	34.9	34.9	34.9	34.9	33.5	27.0	17.1	8.8	5.2	2.6	0.9
0.7	22.5	22.5	22.5	22.5	21.6	18.6	14.7	7.1	3.4	1.7	0.70	0.1
0.9	15.0	15.0	15.0	14.8	13.1	10.8	7.4	3.3	1.3	0.60	0.20	
1.1	10.7	10.7	10.6	10.1	8.4	6.7	3.8	1.5	0.55	0.10	0.03	
1.3	8.0	8.0	7.8	7.2	5.6	4.2	2.1	0.75	0.25	0.02		
1.5	6.4	6.4	6.1	5.35	4.0	2.6	1.3	0.48	0.15			
1.7	5.25	5.20	4.80	4.10	2.98	1.75	0.80	0.30	0.05			
1.9	4.38	4.30	3.85	3.16	2.15	1.15	0.50	0.18				
2.1	3.67	3.56	3.08	2.47	1.65	0.80	0.33	0.10				
2.3	3.13	3.00	2.50	1.98	1.23	0.62	0.23	0.04				
2.5	2.63	2.48	2.03	1.55	0.94	0.40	0.16	0.02				
2.7	2.22	2.04	1.65	1.20	0.70	0.30	0.10					
2.9	1.88	1.69	1.35	0.95	0.52	0.22	0.06					
3.1	1.60	1.41	1.09	0.74	0.39	0.15	0.04					
3.3	1.37	1.18	0.90	0.58	0.29	0.10	0.03					
3.5	1.15	0.97	0.72	0.44	0.21	0.06	0.02					
3.7	0.96	0.79	0.57	0.32	0.15	0.03						
3.9	0.80	0.65	0.45	0.25	0.10	0.02						
4.1	0.68	0.54	0.36	0.19	0.07	0.01						
4.3	0.59	0.46	0.30	0.14	0.05							
4.5	0.50	0.38	0.24	0.10	0.03							
4.7	0.42	0.31	0.19	0.07	0.02							
4.9	0.35	0.25	0.15	0.05	0.01							
5.1	0.29	0.20	0.12	0.03								
5.3	0.24	0.15	0.09	0.02								
5.5	0.20	0.11	0.07									
5.7	0.16	0.08	0.05									
5.9	0.13	0.05	0.03									
6.1	0.10	0.03	0.01									
6.3	0.08	0.02										
6.5	0.07	0.01										
6.7	0.06	0.005										
6.9	0.05											
7.1	0.04											

removed with chromic acid mixture (.5 per cent. CrO_3 + .5 per cent. H_2SO_4), and photomicrographs made. Blank controls with the $NaHCO_3$, etc., showed practically no difference from untreated plates. From the photomicrographs of the residual silver halide grains, size-frequency curves were constructed of the original and residual grains in different exposure steps.

Tables XIII and XIV give the frequency or distribution data of the residual grains. (Taken from the smoothed curves as illustrated in Figs. 3 and 4.)

TABLE XIV.

Graflex CrO_3 Treated. Residual Grains $\times 10^{-5}$/ cm.² From Smooth Curves.

Class Size.	Original −Fog.	Steps 1 to 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
0.11	45.1		45.1	45.1	45.1	45.1	42.8	39.1	36.2
0.3	44.2		44.2	44.2	44.2	43.8	39.8	31.3	26.5
0.5	34.9		34.9	34.9	34.9	32.6	28.0	20.2	14.7
0.7	22.5		22.5	22.0	20.6	18.5	14.9	9.5	6.0
0.9	15.0		14.3	13.25	11.9	10.3	7.9	4.1	2.20
1.1	10.7		9.30	8.50	7.5	6.2	4.10	1.85	0.81
1.3	8.0		6.50	5.85	5.05	4.00	2.45	0.95	0.32
1.5	6.4		4.90	4.30	3.70	2.70	1.56	0.50	0.18
1.7	5.25		3.85	3.34	2.80	1.90	1.03	0.35	0.08
1.9	4.38		3.10	2.66	2.15	1.40	0.69	0.20	0.03
2.1	3.67		2.52	2.15	1.65	1.03	0.46	0.13	
2.3	3.13		2.09	1.74	1.31	0.76	0.30	0.08	
2.5	2.63		1.73	1.40	1.02	0.56	0.21	0.04	
2.7	2.22		1.43	1.12	0.81	0.41	0.13	0.02	
2.9	1.88		1.19	0.90	0.61	0.29	0.07	0.01	
3.1	1.60		0.99	0.73	0.48	0.20	0.04		
3.3	1.37		0.83	0.59	0.37	0.14	0.02		
3.5	1.15		0.68	0.47	0.28	0.09			
3.7	0.96		0.65	0.37	0.20	0.06			
3.9	0.80		0.48	0.30	0.15	0.03			
4.1	0.68		0.38	0.24	0.11	0.01			
4.3	0.59		0.32	0.20	0.080				
4.5	0.50		0.265	0.160	0.060				
4.7	0.42		0.215	0.115	0.040				
4.9	0.35		0.172	0.098	0.025				
5.1	0.29		0.138	0.073	0.015				
5.3	0.24		0.110	0.055	0.008				
5.5	0.20		0.090	0.040	0.002				
5.7	0.16		0.070	0.029					
5.9	0.13		0.055	0.020					
6.1	0.10		0.040	0.013					
6.3	0.08		0.031	0.009					
6.5	0.07		0.026	0.006					
6.7	0.06		0.021	0.004					
6.9	0.05		0.016	0.002					
7.1	0.04		0.010						

Too erratic to determine.

From the plotted data smoothed curves were drawn through the points, without attempting to fit an equation, since previous work had shown the Graflex emulsion to be unrepresentable by a simple equation. At this stage the "clumping" effect also was neglected. To obtain the distribution of the developed grains the

FIG. 5.

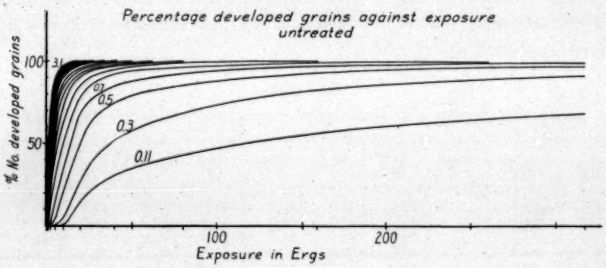
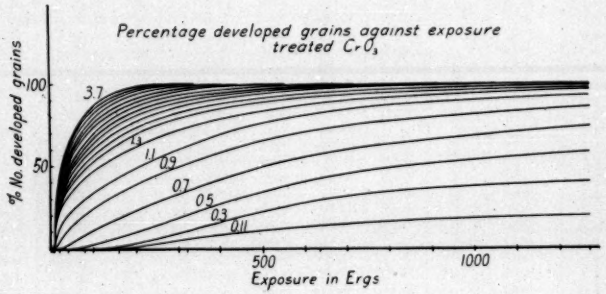


FIG. 6.



"residual" curves were subtracted from the original frequency curve, less "fog" which only amounted to about 3 per cent. of the number of grains.

Dividing the number of developed by that of the original grains in each class size the per cent. developed grains were

obtained. These values were plotted against grain size and against exposure. The results are given in Tables XV and XVI and Figs. 5, 6, 7 and 8.[53]

FIG. 7.

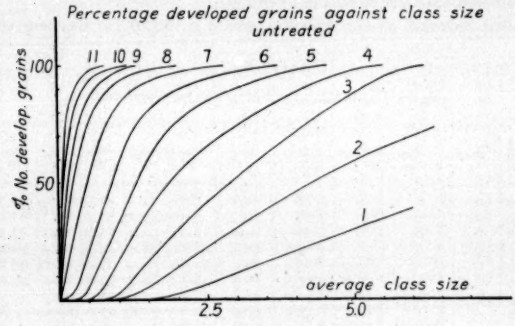
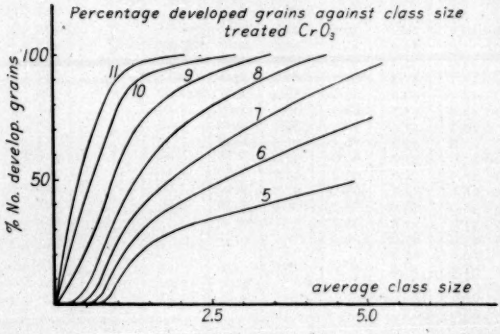


FIG. 8.



Furthermore, the ratios of untreated to treated grains for corresponding exposures are given in Table XVII.

[53] Values for the lowest exposures have been omitted, as the accuracy was quite small.

With some few exceptions, the ratios show a general decrease (towards unity as limit) with increasing grain size (and with increasing exposure). This means that the effect of chromic acid is greater on the small grains than on the large, but this selectivity is diminished as the absolute exposure is increased.

Some reversal of this effect appears to occur on passing to the

TABLE XV.

Graflex Untreated. Percentage Grains Developed.

Class Size.	Orig. Emul.	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
.11	100	0.	0.	0.	0.	0.	0.9	11.8	31.0	42.4	56.1	68.7
.3	100	0.	0.	0.	0.	0.	5.0	27.2	52.0	68.1	82.4	91.4
.5	100	0.	0.	0.	0.	4.0	22.6	51.0	74.8	85.1	92.5	97.4
.7	100	0.	0.	0.	4.0	17.3	34.7	68.4	84.9	92.4	96.9	99.6
.9	100	0.	0.	1.3	13.0	28.0	50.6	78.6	92.0	96.0	98.7	100.0
1.1	100	0.	0.9	5.6	21.5	38.5	64.5	86.0	94.8	99.1	99.8	
1.3	100	0.	2.5	10.0	30.0	48.8	73.7	90.6	96.9	99.7	100.0	
1.5	100	0.	4.7	16.4	37.5	59.4	79.7	92.6	97.6	100.0		
1.7	100	1.0	8.57	21.9	43.3	66.6	84.8	94.3	99.0			
1.9	100	1.8	12.1	27.8	50.9	73.7	88.6	95.9	100.0			
2.1	100	3.0	16.1	32.7	55.0	78.2	91.0	97.3				
2.3	100	4.2	20.1	36.8	60.7	81.5	92.7	98.8				
2.5	100	5.7	22.8	41.1	64.3	84.8	93.9	99.2				
2.7	100	8.1	25.7	46.0	68.5	85.5	95.5	100.0				
2.9	100	10.1	28.2	49.5	72.3	88.3	96.8					
3.1	100	11.9	31.9	53.8	75.6	90.7	97.5					
3.3	100	13.9	34.3	57.6	78.8	92.7	98.6					
3.5	100	15.7	37.4	61.7	81.7	94.8	99.6					
3.7	100	17.7	40.6	64.6	84.4	96.9	100.0					
3.9	100	18.8	43.7	68.8	87.5	97.5						
4.1	100	20.6	47.1	72.1	89.7	98.6						
4.3	100	22.0	49.2	76.3	91.5	100.0						
4.5	100	24.0	52.0	80.0	94.0							
4.7	100	26.2	54.8	83.4	95.3							
4.9	100	28.6	57.2	85.7	97.2							
5.1	100	31.0	58.6	89.7	100.0							
5.3	100	37.5	62.5	91.7								
5.5	100	45.0	65.0	100.0								
5.7	100	50.0	68.8									
5.9	100	61.5	77.0									
6.1	100	70.0	90.0									
6.3	100	75.0	100.0									
6.5	100	85.7										
6.7	100	92.5										
6.9	100	100.0										
7.1	100											
t in sec. =		0.5	1.	2.	4.	8.	16.	32.	64.	128.	256.	512.
$n \times 10^{12*} =$		0.074	0.148	0.295	0.59	1.18	2.35	4.7	9.4	18.8	37.6	75.2
E in erg =		0.338	0.675	1.25	2.49	4.98	9.95	19.9	39.8	79.5	159.	318.

* $\lambda = 460\ \mu\mu$.

lowest exposures, but it cannot be stated at present if this is real or apparent.

2. *Densitometry.*—Another series was run using the same

TABLE XVI.

Graflex CrO_3 Treated. Percentage Grains Developed.

Class Size.	Orig. Emul.	Steps 1 to 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
0.11	100		0.	0.	0.	0.	5.1	13.3	19.7
0.3	100		0.	0.	0.	1.1	10.0	29.2	40.1
0.5	100		0.	0.	0.	6.6	19.8	42.1	57.9
0.7	100		0.	2.2	8.4	17.8	33.8	57.1	73.3
0.9	100		4.7	11.7	20.7	33.3	47.3	72.7	85.3
1.1	100		13.1	20.6	29.9	42.0	61.7	82.7	92.4
1.3	100		18.8	26.9	36.9	50.0	69.4	88.1	96.0
1.5	100		23.4	32.8	42.2	56.6	76.2	92.2	97.2
1.7	100		26.7	36.4	46.7	63.8	80.4	93.3	98.5
1.9	100		29.2	39.3	50.9	68.0	84.2	95.4	99.3
2.1	100		31.3	41.4	55.0	72.0	87.4	96.5	100.0
2.3	100		33.2	44.4	58.2	75.7	90.4	97.5	
2.5	100		34.2	46.8	61.2	78.7	92.0	98.5	
2.7	100		35.6	49.5	63.5	81.6	94.2	99.5	
2.9	100		36.7	52.1	67.6	84.6	96.3	100.0	
3.1	100	Too erratic to determine.	38.1	54.4	70.0	87.5	97.5		
3.3	100		39.4	56.9	73.0	89.8	98.6		
3.5	100		40.9	59.1	75.6	92.2	100.0		
3.7	100		41.7	61.5	79.2	93.8			
3.9	100		42.5	62.5	81.2	96.2			
4.1	100		44.1	64.7	83.8	98.5			
4.3	100		45.8	66.1	86.4	100.0			
4.5	100		47.0	68.0	88.0				
4.7	100		48.8	70.2	90.5				
4.9	100		50.6	72.0	92.9				
5.1	100		52.4	74.8	94.8				
5.3	100		54.2	77.0	96.7				
5.5	100		55.0	80.0	99.0				
5.7	100		56.3	81.9	100.0				
5.9	100		57.7	84.6					
6.1	100		60.0	87.0					
6.3	100		61.3	88.7					
6.5	100		62.9	91.4					
6.7	100		65.0	93.3					
6.9	100								
7.1	100								
t in sec. =			32.	64.	128.	256.	512.	1024.	2048.
$n \times 10^{12}$ =			4.7	9.4	18.8	37.6	75.2	150.4	300.8
E in erg.			19.9	39.8	79.5	159.	318.	636.	1272.

treatment, but instead of removing the silver the undeveloped silver halide was fixed out and the "densities" measured with a thalofide cell.[54]

[54] By Mr. A. L. Schoen of the Physics Department. The instrument is described in the *J. Am. Opt. Soc.*, 7, 483 (1923).

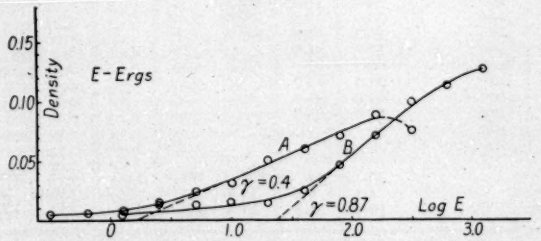
TABLE XVII.

Graflex Ratio. Untreated to Treated.

Class Size.	Steps 5/3	Steps 6/4	Steps 7/5	Steps 8/6	Steps 9/7	Steps 10/8	Steps 11/9
0.11				∞	(2.31)	2.33	2.15
0.3				4.54	2.72	(1.78)	1.70
0.5			∞	3.42	2.57	1.78	1.47
0.7		1.82	2.06	1.95	2.02	1.49	1.26
0.9	0.28	1.11	(1.35)	(1.52)	1.66	1.27	1.13
1.1	0.43	1.04	(1.29)	1.54	1.39	1.15	1.07
1.3	0.53	1.11	(1.32)	1.47	1.30	1.10	1.04
1.5	0.70	1.14	1.41	1.41	1.22	1.06	1.03
1.7	0.82	1.19	1.43	1.33	1.17	1.06	1.02
1.9	0.95	1.29	1.45	1.30	1.30	1.14	1.01
2.1	1.04	1.33	1.42	1.26	1.11	1.04	1.00
2.3	1.11	1.37	1.40	1.22	1.09	1.03	
2.5	1.20	1.37	1.39	1.19	1.08	1.01	
2.7	1.29	1.38	1.36	1.17	1.06		
2.9	1.35	1.39	1.31	1.14	1.04		
3.1	1.41	1.39	1.30	1.11	1.03		
3.3	1.46	1.38	1.27	1.10			
3.5	1.51	1.38	1.25	1.08			
3.7	1.55	1.37	1.22	1.07			
3.9	1.62	1.40	1.20	1.04			
4.1	1.63	1.39	1.18				

In Tables XVIII and XIX are given the densities, corresponding exposures, and exposure logs, and in Fig. 9 the

FIG. 9.



curves *A* and *B* show the untreated and treated emulsion results, respectively. The increase in the steepness of the curve is explanable on the ground of the reduction of the sensitivity

TABLE XVIII.

Density-Exposure Values, Untreated Graflex Emulsion. One-grain-layer Plate.

E in Ergs.	Log *E*	D_1	D_2	D_3	D_4	D_5	D_6	D_m	Step No.
0.31	$\bar{1}$.491	.0043	.0000	.0048	.0086	.0000	.0034	.0042	1
0.62	$\bar{1}$.792	.0086	.0022	.0065	.0030	.0048	.0000	.0050	2
1.24	0.093	.0191	.0022	.0111	.0000	.0073	.0000	.0066	3
2.48	0.395	.0294	.0060	.0228	.0170	.0048	.0034	.0139	4
4.97	0.696	.037	.0120	.0588	.0199	.0133	.0145	.0237	5
9.94	0.997	.0386	.0170	.0611	.0199	.0228	.0289	.0314	6
19.88	1.299	.0607	.0358	.0906	.0314	.0434	.0461	.0513	7
39.75	1.599	.0618	.0473	.0806	.0445	.0445	.0817	.0601	8
79.5	1.900	.0849	.0418	.0806	.0596	.0697	.0941	.0713	9
159.0	2.201	.0871	.0565	.1052	.0853	.0697	.1222	.0877	10
318.0	2.502	.0607	.0810	.0871	.0781	.0759	.0685	.0752	11

TABLE XIX.

Density-Exposure Values, CrO_3 Treated Graflex Emulsion. One-grain-layer Plate.

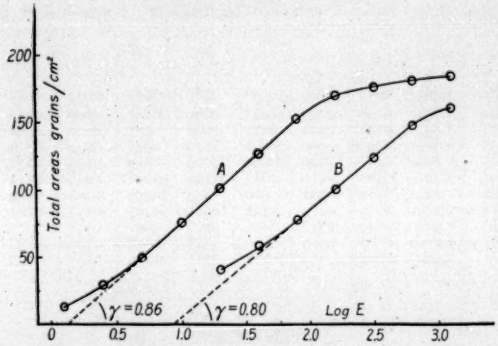
E in Ergs.	Log *E*	D_1	D_2	D_3	D_4	D_5	D_6	D_m	Step No.
1.24	0.093	.0021	.0178	.0038	.0000	.0021	.0000	.0043	1
2.48	0.395	.0115	.0244	.0119	.0086	.0115	.0086	.0128	2
4.97	0.696	.0178	.0293	.0000	.0115	.0115	.0056	.0126	3
9.94	0.997	.0115	.0350	.0000	.0145	.0257	.0021	.0148	4
19.88	1.299	.0051	.0350	.0060	.0195	.0145	.0056	.0142	5
39.75	1.599	.0051	.0386	.0149	.0350	.0386	.0145	.0245	6
79.5	1.900	.0178	.0685	.0488	.0599	.0461	.0386	.0466	7
159.0	2.201	.0350	.0809	.0755	.0969	.0726	.0659	.0711	8
318.0	2.502	.0468	.1172	.0889	.1212	.1105	.1078	.0987	9
636.0	2.804	.0625	.1616	.1112	.1142	.1215	.1078	.1131	10
1272.	3.104	.1075	.1798	.1112	.1649	.1076	.0909	.1270	11

range by chromic acid treatment.[55] There is, however, a discrepancy if instead of *density* the total area of developed grains is plotted in both cases (Fig. 10). Here the curves are *parallel*, only the "speed" being altered, *i.e.*, the intercept on the log *E* axis. The reasons for this disagreement are not yet clear;

[55] *Cf.* paper sent to Faraday Society Symposium, May, 1923, also G. I. Higson and F. C. Toy, *Phot. J.*, **63**, 68 (1923).

Similar results were obtained by using an acid permanganate solution in place of the chromic acid. The concentration of $KMnO_4$ required to give approximately equivalent results, however, was much lower (about $^1/_5$) than that of the CrO_3.

FIG. 10.



they may be connected with the uncertainty in the correct relation of density = log $\frac{1}{T}$ with *mass* of material for one-grain layers, or in the method of determining density by means of the thalofide cell densitometer.[56] Figs. 11*a* and 11*b* and 12*a* and 12*b* show photomicrographs of the untreated and CrO_3-treated grains in alternate exposure steps, (*a*) with developed silver and (*b*) the same places after removal of the silver. The arrows indicate where clumping has taken place in the lower and medium exposures.

3. *Action of Chromic Acid and Iodide on One-grain Layers.*—In Table XX are given the effects on the developable threshold values.

The values given in this table are only rough approximations. In the above work the same developer (Fe″ oxalate) was used throughout. Further work is planned making use of a special iodide developer as suggested by Renwick.[57]

As shown by Renwick [58] and corroborated by our own experiments, treatment with iodide at 1 per cent. concentration shatters

[56] *Cf.* P. G. Nutting, *Phil. Mag.*, **26**, 423 (1913); also L. Silberstein, *ibid.*, **45**, 1069 (1923).

[57] F. F. Renwick, *J. Soc. Chem. Ind.*, **39**, 156T (1920).

[58] F. F. Renwick, *loc. cit.*

TABLE XX.

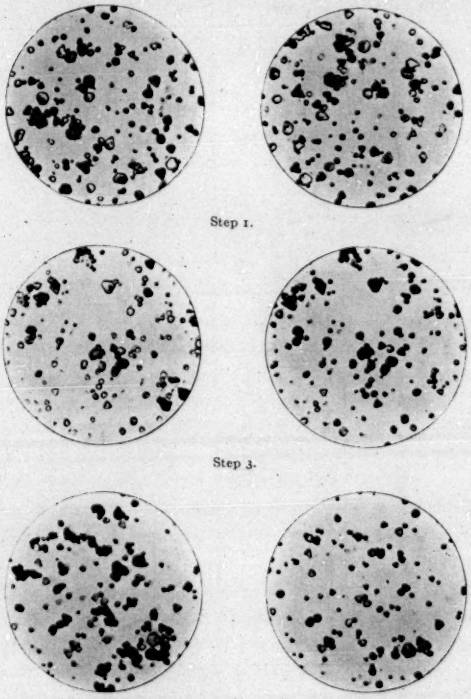
Relative Sensitivity, Based on Developable Threshold Value of CrO_3 and KI Treated One-layer Plates.

	1	2	3	4	5
	Blank; exposed without treatment.	0.5% CrO_3 + 0.2% H_2SO_4; washed in 1% $NaHCO_3$; then in 1% HCl; then in H_2O; dried; exposed and developed.	0.5% KI for 15 min.; washed in H_2O; dried; exposed and developed.	CrO_3 treatment as in (2) followed by KI as in (3); washed, dried, etc.	CrO_3 as in (2); KI as in (3); CrO_3 again as in (2); washed, dried, etc.
Relative exposure of step 1, for each treatment.	1	4	16	16	16
First visible step No.	2	5	7	7	11
Corresponding relative exposure of first visible step.	1	32	512	512	16,384 if at all.

the silver halide grain into a mosaic of finer particles. Developability by ordinary developers is lowered considerably more than by chromic acid.

Since AgI is much less soluble than AgBr, it is probable that

FIG. 11*a*.



Step 1.

Step 3.

Step 5.

Before Ag removed. After Ag removed.

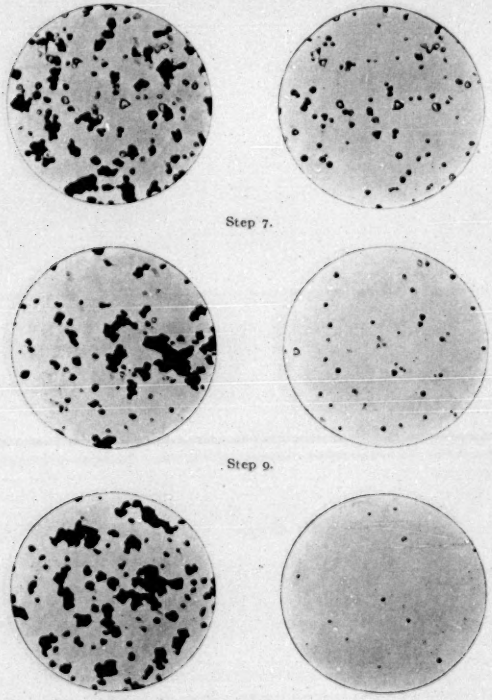
Seed Graflex untreated, exposed and developed.

this effect is primarily a question of reducing the silver-ion solution tension. The fact that AgI, as shown by Lüppo-Cramer and by Renwick, is relatively more easily developed, and gives

higher sensitivity than AgBr, with physical developers, which supply free Ag^+ ions, supports this view.

The existence of internal sensitive nuclei or spots in the grain prior to exposure seems to be substantiated by the following

FIG. 11*b*.

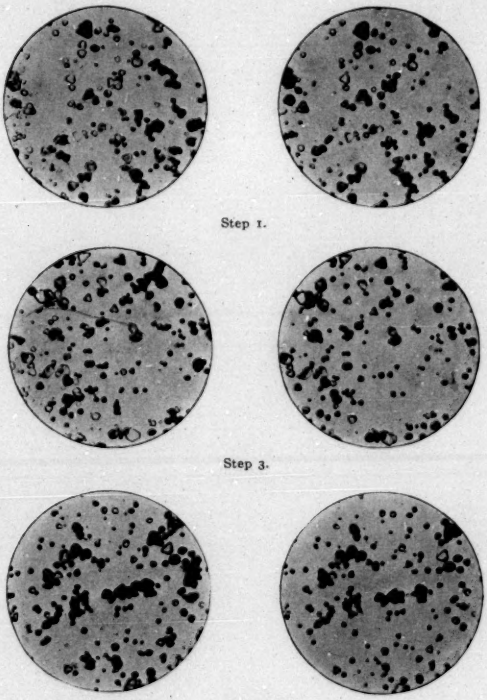


Untreated, exposed, etc.

results: Consider two sets of AgBr grains, one from which the surface nuclei have been largely removed by chromic acid, the other not. On treating both with 1 per cent. KI we should expect

the grain stripped of surface nuclei to show still less "sensitivity" than the untreated one; actually they are both of the same (lowered) sensitivity with chemical development. Microscopic examination of the developed grains treated with CrO_3 followed

FIG. 12*a*.

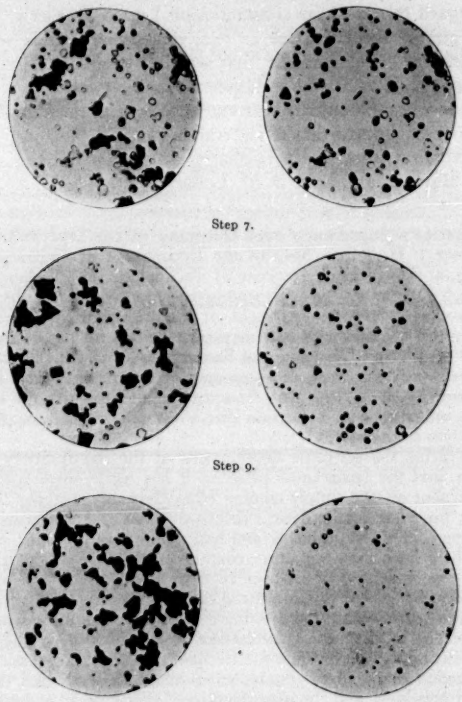


Seed Graflex. CrO_3 treated.

by KI shows that they develop from the centre outward. This also tends to support the view that occluded internal nuclei are freed by the iodide, although it may be due to persistence of

some AgBr. Much more conclusive evidence of the freeing of internal sensitivity nuclei is the fact that further treatment, after the KI, by CrO_3, again enormously reduces the sensitivity (at least 16,000 times the original sensitivity).

FIG. 12*b*.



Step 7.

Step 9.

Step 11.

With Ag. Without Ag.

CrO_3 treated.

The results with CrO_3 alone indicate that the "sensitivity nuclei" are only incompletely removed by CrO_3—actual figures with sensitometric control on different plates will be given in a

later paper. The subsequent action of KI and CrO_3 indicates that much of the sensitivity is occluded, and may be released by certain means. The action of iodide here is in good agreement with the part played by the "latent image," and points to a similar nature of the "latent image" and "sensitivity," *viz.*, colloid silver. We regard this work as substantiating Lüppo-Cramer's "Keimblosslegung" theory so far as relatively strong iodide solutions are concerned, but consider that with the very dilute solutions adsorption effects are more important.

The work reported has been extended over a considerable time, and our thanks are due to several helpers in the experimental and statistical work and particularly W. H. Davis, R. F. Quirk, A. M. Burgess, and Miss B. M. LeBar.

America's Supremacy over Germany in the Dye Industry.—Professor J. H. James, head of the Department of Chemical Engineering, at the Carnegie Institute of Technology, in Pittsburgh, says that such supremacy "is evidenced by the fact that the United States now produces about 93.5 per cent. of the dyes actually consumed in the country. While it is still necessary for us to import the other 6.5 per cent. from Germany and Switzerland, and which percentage represents only the latest developments of dye manufacture in these two countries, it is clear that America's ability to shift for itself in the dye industry is an indication that, eventually, it will supply most of the dyes to the world."

In tracing the scientific development of the dye industry in this country, and the remarkable progress it has made since 1914 when the war shut off the supply coming from Germany, forcing America to shift for itself for its dyes, Professor James said: "Germany was the home of the dye industry and had done more scientific research along these lines than any other country on the face of the globe up to the time of the war. From 1870 to 1914, which is commonly referred to by students of industrial chemistry as the 'golden age' of German dye-stuff manufacture, there took place the most wonderful development in chemical manufacture in the history of the world. It was during that period that the German government extended long-term credits to the firms interested in research work and development of this kind, and the manufacture of this product. And it was during that time that Germany made itself known everywhere as the leading dye country of the world." H. L.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP, MAY 16, 1923.

At the Stated Meeting of the Committee on Science and the Arts, held January 3, 1923, the following resolutions were adopted:

"*Resolved*, That The Franklin Medal be awarded to General G. Ferrié in recognition of his long-continued and successful researches in the field of radiotransmission of intelligence and their splendid and successful military applications, and of his eminent success in the organization and directing of the communication service of the French Army during the World War."

"*Resolved*, That The Franklin Medal be awarded to Dr. Albert A. Michelson in recognition of his numerous and signally fruitful researches in physical science, especially his brilliant discoveries in the fields of optics and astrophysics."

CORRESPONDENCE.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY — FEBRUARY 2, 1923.

General G. Ferrié,
Inspecteur des Services de la Télégraphie Militaire et des Transmissions,
51 bis, Boulevard Latour-Maubourg,
Paris, France.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for "the recognition of those workers in physical science and technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

> "That The Franklin Medal be awarded to General G. Ferrié in recognition of his long-continued and successful researches in the field of radiotransmission of intelligence and their splendid and successful military applications, and of his eminent success in the organization and directing of the communication service of the French Army during the World War."

The medal and accompanying certificate are being prepared, and His Excellency M. Jusserand, your Government's Ambassador at Washington is

being requested to come to the Institute on the afternoon of Wednesday, May 16th, to receive from our President, Dr. Walton Clark, this medal and certificate on behalf of his Government for you.

I am,

Respectfully,

(Signed) R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY — FEBRUARY 2, 1923.

His Excellency M. J. J. Jusserand,
Ambassador Extraordinary and Plenipotentiary,
Republic of France, French Embassy,
Washington, D. C.

YOUR EXCELLENCY:

I have the honour to inform you that The Franklin Medal has again been awarded to one of your distinguished countrymen, General G. Ferrié, Inspecteur des Services de la Télégraphie Militaire et des Transmissions, 51 bis, Boulevard Latour-Maubourg, Paris, France. The award is minuted as follows:

> "That The Franklin Medal be awarded to General G. Ferrié in recognition of his long-continued and successful researches in the field of radiotransmission of intelligence and their splendid and successful military applications, and of his eminent success in the organization and directing of the communication service of the French Army during the World War."

The medal and accompanying certificate are being prepared and I am requested on behalf of our Management to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 16th, to receive this medal and certificate from our President for transmission to General Ferrié.

Two Franklin Medals have been awarded this year, one to General Ferrié and one to Dr. A. A. Michelson, Professor of Physics, The University of Chicago.

Our President, Dr. Walton Clark, will shortly extend to you and to Doctor Michelson an invitation to be the guests of honour at a dinner he will give following the presentation ceremonies.

I am

Your Excellency's very humble servant,

(Signed) R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY FEBRUARY 2, 1923.

Dr. A. A. Michelson.
Professor of Physics,
The University of Chicago,
Chicago, Illinois.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for "the recognition of those workers in physical science and technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

> "That The Franklin Medal be awarded to Dr. A. A. Michelson in recognition of his numerous and signally fruitful researches in physical science, especially his brilliant discoveries in the fields of optics and astrophysics."

The medal and accompanying certificate are being prepared and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 16th, to receive this medal and certificate from our President, Dr. Walton Clark.

I am,
Respectfully,
(Signed) R. B. OWENS,
Secretary.

AMBASSADE
DE LA REPUBLIQUE FRANCAISE
AUX ETATS-UNIS

WASHINGTON, LE FEBRUARY 3, 1923.

DEAR SIR:

My country is sure to deeply appreciate The Franklin Institute's decision to award once more The Franklin Medal to a compatriot of ours, namely, General Ferrié, whose great services in the line of wireless communications will thus be recognized.

It is not possible for me, as you will certainly understand, to be sure in advance that I shall be free on the 16th of May and able to avail myself of the kind invitation of your Institute. If I were prevented to go, I would ask the permission to, at least, be represented on that occasion.

Believe me, with much gratitude,
Sincerely yours,
(Signed) JUSSERAND.

MR. R. B. OWENS,
Secretary, The Franklin Institute,
Philadelphia, Pa.

THE UNIVERSITY OF CHICAGO
RYERSON PHYSICAL LABORATORY

FEBRUARY 7, 1923.

MR. R. B. OWENS,
Secretary, Franklin Institute.

DEAR MR. OWENS:

I have the honor to acknowledge the receipt of your letter announcing the award of The Franklin Medal, and wish to express my gratification and high appreciation of the honor.

I am very strenuously occupied with preliminary experiments preparatory to work at Mt. Wilson, and it may be difficult for me to spare the time for accepting your kind invitation to be present at the meeting of the Institute—especially as I am obliged to attend the Meeting of the National Academy in April.

Very sincerely yours,
(Signed) A. A. MICHELSON.

MINISTÈRE DE LA GUERRE
GÉNIE

PARIS LÉ 24 FEVRIER, 1923,
51 bis, Boulevard Latour-Maubourg (7. arr.)

LE GÉNÉRAL FERRIÉ
INSPECTEUR DES SERVICES DE LA TÉLÉGRAPHIE MILITAIRE ET DES TRANSMISSIONS

Á MONSIEUR R. B. OWENS,
Secrétaire de l'Institut Franklin,
Philadelphia.

CHER MONSIEUR:

Je viens de trouver, à mon retour d'une longue absence, la lettre par laquelle vous m'annoncez que l'Institut Franklin m'a décerné la "Médaille Franklin," et je me hâte de vous dire toute ma gratitude pour le grand honneur que m'a été fait. Les termes de la décision de l'Institut, que vous avez bien voulu me communiquer, me touchent d'autant plus qu'ils visent notamment les Services que j'ai pu rendre pendant la guerre mondiale, alors que les Armées de nos deux Pays combattaient côté à côte pour le Droit et la Civilisation, et que leurs "Signal Corps" mettaient en commun toutes leurs ressources, avec la cordialité et l'union les plus complètes. Les sentiments qui sont nés dans de telles conditions ont dans nos cœurs des racines tellement profondes qu'ils ne pourront plus en être détachés.

Je m'efforce maintenant d'étendre aux besoins du temps de paix et au développement de la science les travaux réalisés ou commencés pour notre défense. Les occupations qui m'incombent ne me permettront pas d'aller moi même recevoir le 16 Mai la Médaille FRANKLIN. Je m'en excuse et je le regrette très vivement.

Veuillez agréer, cher Monsieur, l'expression de mes meilleurs sentiments.
(Signed) FERRIÉ.

AMBASSADE
DE LA REPUBLIQUE FRANCAISE
AUX ETATS-UNIS

WASHINGTON, LE APRIL 25, 1923.

DEAR MR. OWENS:

Referring to previous correspondence and in the last instance to your letter of February the 6th, concerning The Franklin Medal awarded to General Ferrié, I want first to say that I hope you are now quite well and have entirely recovered from the attack of pneumonia from which you suffered this winter.

Concerning the intended ceremony at Philadelphia in the afternoon of the 16th of May, I have to say, to my regret that obligations which I have to fulfill in New York at the same time and which I cannot possibly waive, will prevent my being present. But I hope that you will allow me to be represented and in the thought that this would be agreeable to you, I have designated for this Colonel Dumont, Military Attaché to this Embassy and a veteran of the Great War; he will certainly be a worthy recipient of the Medal distined for one of his brother officers.

Any communication sent to him care of this Embassy would be sure to reach him.

Believe me, with best regards,
Very sincerely yours,

(Signed) JUSSERAND.

MR. R. B. OWENS,
Secretary of The Franklin Institute,
Philadelphia,
Pa.

AMBASSADE
DE LA REPUBLIQUE FRANCAISE
AUX ETATS-UNIS

WASHINGTON, LE MAY 5, 1923.

DEAR MR. SECRETARY:

I have received this morning the kind invitation of the Officers and Members of The Franklin Institute for Wednesday, May the 16th, at three thirty.

As I wrote to you before, obligations which I must needs fulfill will prevent my being present and having the honor of receiving The Franklin Medal on behalf of General Ferrié, but Colonel Dumont, Military Attaché to this Embassy, will act in my stead.

Believe me, with best regards,
Sincerely yours,

(Signed) JUSSERAND.

MR. R. B. OWENS,
Secretary of The Franklin Institute,
Philadelphia,
Pa.

THE UNIVERSITY OF CHICAGO
RYERSON PHYSICAL LABORATORY

FEBRUARY 7, 1923.

MR. R. B. OWENS,
Secretary, Franklin Institute.

DEAR MR. OWENS:

I have the honor to acknowledge the receipt of your letter announcing the award of The Franklin Medal, and wish to express my gratification and high appreciation of the honor.

I am very strenuously occupied with preliminary experiments preparatory to work at Mt. Wilson, and it may be difficult for me to spare the time for accepting your kind invitation to be present at the meeting of the Institute—especially as I am obliged to attend the Meeting of the National Academy in April.

Very sincerely yours,
(Signed) A. A. MICHELSON.

MINISTÈRE DE LA GUERRE
GÉNIE

PARIS LÉ 24 FEVRIER, 1923,
51 bis, Boulevard Latour-Maubourg (7. arr.)

LE GÉNÉRAL FERRIÉ
INSPECTEUR DES SERVICES DE LA TÉLÉGRAPHIE MILITAIRE ET DES TRANSMISSIONS

A MONSIEUR R. B. OWENS,
Secrétaire de l'Institut Franklin,
Philadelphia.

CHER MONSIEUR:

Je viens de trouver, à mon retour d'une longue absence, la lettre par laquelle vous m'annoncez que l'Institut Franklin m'a décerné la "Médaille Franklin," et je me hâte de vous dire toute ma gratitude pour le grand honneur que m'a été fait. Les termes de la décision de l'Institut, que vous avez bien voulu me communiquer, me touchent d'autant plus qu'ils visent notamment les Services que j'ai pu rendre pendant la guerre mondiale, alors que les Armées de nos deux Pays combattaient côté à côte pour le Droit et la Civilisation, et que leurs "Signal Corps" mettaient en commun toutes leurs ressources, avec la cordialité et l'union les plus complètes. Les sentiments qui sont nés dans de telles conditions ont dans nos cœurs des racines tellement profondes qu'ils ne pourront plus en être détachés.

Je m'efforce maintenant d'étendre aux besoins du temps de paix et au développement de la science les travaux réalisés ou commencés pour notre défense. Les occupations qui m'incombent ne me permettront pas d'aller moi même recevoir le 16 Mai la Médaille FRANKLIN. Je m'en excuse et je le regrette très vivement.

Veuillez agréer, cher Monsieur, l'expression de mes meilleurs sentiments.
(Signed) FERRIÉ.

AMBASSADE
DE LA REPUBLIQUE FRANCAISE
AUX ETATS-UNIS

WASHINGTON, LE APRIL 25, 1923.

DEAR MR. OWENS:

Referring to previous correspondence and in the last instance to your letter of February the 6th, concerning The Franklin Medal awarded to General Ferrié, I want first to say that I hope you are now quite well and have entirely recovered from the attack of pneumonia from which you suffered this winter.

Concerning the intended ceremony at Philadelphia in the afternoon of the 16th of May, I have to say, to my regret that obligations which I have to fulfill in New York at the same time and which I cannot possibly waive, will prevent my being present. But I hope that you will allow me to be represented and in the thought that this would be agreeable to you, I have designated for this Colonel Dumont, Military Attaché to this Embassy and a veteran of the Great War; he will certainly be a worthy recipient of the Medal distined for one of his brother officers.

Any communication sent to him care of this Embassy would be sure to reach him.

Believe me, with best regards,
Very sincerely yours,

(Signed) JUSSERAND.

MR. R. B. OWENS,
Secretary of The Franklin Institute,
Philadelphia,
Pa.

AMBASSADE
DE LA REPUBLIQUE FRANCAISE
AUX ETATS-UNIS

WASHINGTON, LE MAY 5, 1923.

DEAR MR. SECRETARY:

I have received this morning the kind invitation of the Officers and Members of The Franklin Institute for Wednesday, May the 16th, at three thirty.

As I wrote to you before, obligations which I must needs fulfill will prevent my being present and having the honor of receiving The Franklin Medal on behalf of General Ferrié, but Colonel Dumont, Military Attaché to this Embassy, will act in my stead.

Believe me, with best regards,
Sincerely yours,

(Signed) JUSSERAND.

MR. R. B. OWENS,
Secretary of The Franklin Institute,
Philadelphia,
Pa.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

MAY 7, 1923.

YOUR EXCELLENCY:

Please accept my best thanks for your kind letter of May 5th.

That you cannot be here on the afternoon of Wednesday, May 16th, is, of course, a matter of regret. If I take no liberty in saying so, I can easily imagine how well every moment of your time is occupied in the highest kind of constructive work, that of bettering an understanding of present day world conditions and maintaining essential international relationships.

Perhaps the Institute's recognition of General Ferrié's splendid work and that of Professor Fabry will have a reflex, however small, in strengthening, if it is possible, those bonds, which, as an Officer in the American Expeditionary Forces, I saw being reforged and welded to a thing of greater strength than I believe the world has ever known before in its history.

The Institute is honoured in having you represented by Colonel Dumont, with whom I have communicated.

Believe me, with kindest regards,
Always sincerely,

(Signed) R. B. OWENS,
Secretary.

His Excellency, M. Jusserand,
Ambassador, Republic of France,
French Embassy,
Washington, D. C.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

MAY 10, 1923.

DEAR COLONEL DUMONT:

An illness has deprived me of the pleasure of before directly communicating with you relative to the visit, I understand through His Excellency, M. Jusserand, it will be agreeable to you to make us on Wednesday, next.

Referring to the enclosed programme, you will note that General J. J. Carty will make a statement relative to the work of General G. Ferrié, and I may say that General Carty will after making such a statement present you to our President to receive for transmission to General Ferrié the Institute's Franklin Medal, accompanying Certificate and Certificate of Honorary Membership.

I also enclose with this an account of last year's May Meeting, which will give you an idea of the very simple procedure which will be followed next Wednesday. If, after receiving for General Ferrié the medal, etc., you should

make a few remarks, all of us here will be greatly pleased. You will not object, I trust, if I say that the Institute's action in awarding The Franklin Medal to General Ferrié gives me personally a very peculiar and very sincere satisfaction. It was my great privilege as a Signal Corps Officer, A.E.F., to know General Ferrié and to be the recipient of many kindnesses extended by him. For him as a scientist, an engineer, and a soldier, I have an intense admiration and for him as a man I have great affection, and I can assure you that my feelings toward him are shared by every American Officer who had the privilege of knowing him.

I am also enclosing a paper "The Scientific Applications of Radio-telegraphy" by General Ferrié, which will be read by our mutual friend, General G. O. Squier, Chief Signal Officer, U. S. Army.

My thought is that it will perhaps be convenient to you and to General Squier to take the Pennsylvania R. R. train leaving Washington at 8.15 A.M., arriving West Philadelphia 11.24, and to have luncheon with me and with Dr. A. A. Michelson at the Philadelphia Club, 1301 Walnut Street, about one o'clock (daylight saving).

I have taken the liberty of asking a few gentlemen to meet you and Doctor Michelson at dinner on Wednesday evening.

Believe me, with kindest regards,

Always sincerely,

(Signed) R. B. OWENS,
Secretary.

Colonel G. A. L. Dumont,
Military Attaché, French Embassy,
Washington, D. C.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE PRESIDENT — MARCH 21, 1923.

DEAR DR. MICHELSON:

I have been very sorry to learn that there is some doubt of your ability to be present at The Franklin Institute on May 16th to receive The Franklin Medal, awarded to you in recognition of your wonderful services to mankind rendered in the field of physical science. I hope very much that you will be able to arrange to be with us to receive the medal in person.

With kind regards,

Respectfully,

(Signed) WALTON CLARK,
President.

Dr. A. A. Michelson,
Professor of Physics,
The University of Chicago,
Chicago, Illinois.

THE UNIVERSITY OF CHICAGO
RYERSON PHYSICAL LABORATORY

MARCH 30, 1923.

MR. WALTON CLARK, M.E., D.Sc.,
President, Franklin Institute.

DEAR DR. CLARK:

I greatly appreciate your letter of the 21st instant. It will be difficult for me to adjust certain engagements to which I am committed, but I am nevertheless glad to accept your kind invitation to be present on May 16 next to receive The Franklin Medal from you.

Very sincerely yours,

(Signed) A. A. MICHELSON.

STATED MEETING

WEDNESDAY, MAY 16, 1923

3.30 O'CLOCK

PROGRAMME

PRESENTATION OF

THE FRANKLIN MEDAL

ACCOMPANYING CERTIFICATE AND CERTIFICATE OF HONORARY MEMBERSHIP

TO

COLONEL G. A. L. DUMONT

MILITARY ATTACHÉ, THE FRENCH EMBASSY

REPRESENTING

HIS EXCELLENCY M. JUSSERAND

AMBASSADOR EXTRAORDINARY AND PLENIPOTENTIARY
THE FRENCH REPUBLIC

FOR

GENERAL G. FERRIÉ

INSPECTOR GENERAL OF MILITARY COMMUNICATIONS
THE FRENCH ARMY

PRESENTATION OF

THE FRANKLIN MEDAL

ACCOMPANYING CERTIFICATE AND CERTIFICATE OF HONORARY MEMBERSHIP

TO

ALBERT A. MICHELSON

PAPERS

THE SCIENTIFIC APPLICATIONS OF RADIOTELEGRAPHY

GENERAL G. FERRIÉ

READ BY MAJOR GENERAL GEORGE OWEN SQUIER
CHIEF SIGNAL OFFICER, U. S. ARMY

LIGHT WAVES IN ASTRONOMY

ALBERT A. MICHELSON

THE PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP TO GENERAL G. FERRIÉ AND DR. A. A. MICHELSON.

IN calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievements and recognized Brigadier-General John J. Carty, Vice-president of the American Telephone and Telegraph Company, who made the following statement relative to the work of General G. Ferrié:

The Franklin Medal was founded in the year 1913 through the beneficence and generosity of Samuel Insull, Esq., of Chicago. The medal is to be awarded from time to time in recognition of the total contributions of individuals to science. The award is to be made without regard to country, and to those who have done most to advance the knowledge of physical science or its applications.

To-day the medal is to be awarded to General G. Ferrié, Inspector-General of Military Communications in the French Army. The award is to be made "In recognition of his long-continued and successful researches in the field of radio transmission of intelligence and their splendid and successful military application, and of his eminent success in the organization and directing of the communication service of the French Army during the World War."

General Ferrié possesses in a high degree the qualities of soldier, scientist, and engineer. He will be remembered as one of the most distinguished pioneers in the art of radio transmission. Since the year 1898 he has devoted himself to the study of the new science, the wonderful possibilities of which were revealed by the work of Branly and Marconi. Independently of others, he developed the electrolytic detector, and he was the first to apply radiotelegraphy in the French colonies, notably between Martinique and Guadeloupe, where the wireless telegraph system which he designed rendered such important service after the destruction of the cable caused by the eruption of Mt. Pelée.

As early as 1903, he began the study and later the construction of a radiotelegraph station on the Eiffel Tower, the first

of the great French stations. Subsequently in Morocco in 1908, he began the establishment of a wireless telegraphic network for military purposes, made up of stations throughout that area, which assured communications between the different units of the expeditionary forces.

During these years he also developed measuring apparatus, providing valuable methods for use in the transmission of time by radiotelegraph, thus contributing to the progress of navigation and the science of geodesy. It is to General Ferrié that France owes the splendid organization of the radiotelegraph service for the French army, and which in the course of the war rendered results of such incalculable value. After the month of July, 1914, he caused the construction of a new radiotelegraph station at Lyons. This was done with remarkable speed, and rendered service of immense consequence, carrying the extra load of messages which could not be carried by the Eiffel Tower. During the war, he organized powerful groups of scientists and engineer officers and university professors who, working under his direction, produced devices of great military value. It was under his direction that apparatus for the sending and receiving of wireless messages using electric valves was put into effect in the French armies, thus giving to the Allies agencies of communication superior to those of the enemy.

He also developed a method of telegraphing through the ground, and for communicating with dirigibles and airplanes. He introduced improved forms of radiogoniometric apparatus for locating the radio stations of the enemy. He did pioneer work in experiments for directing the course of airships and warplanes operating without pilots.

He is a member of many commissions and technical committees, both national and international, where his scientific ability and large experience of affairs are productive of great good. He was a member of the International Radiotelegraph Conference at London in 1912, the International Congress of Time in 1913, the Interallied Telegraphic Conference of 1920, the Interallied Technical Committee of Wireless Telegraphy, and was technical advisor at the International Communications Conference recently held at Washington.

He has received numerous decorations, both French and foreign, including the Distinguished Service Medals of the United

States Army and of the United States Navy. He is Doctor Honoris Causa of Oxford University, England. The Institute of France awarded him the Kastner Boursault prize in 1904, the Wilde prize in 1912, and the Osiris prize in 1921. Last year he was elected to the Academy of Science of the Institute of France, the highest scientific honour conferred in his country.

In the estimation of the scientists and radio engineers of all the nations, the work of General Ferrié in radio transmission holds a foremost place. His comprehensive knowledge of radio engineering is based upon a sound understanding and thorough grasp of the fundamental scientific principles involved. His remarkable ingenuity and his rare sense of practical values have enabled him to apply to civil affairs the results of pure scientific research, with distinguished success. His professional training as a soldier and his knowledge of military engineering have enabled him to apply his fundamental scientific knowledge to military problems with even greater results. During the period of the colossal conflict of the armies of the world, his modest bearing and the unobtrusive character of his labors served for a time to veil their importance, but now that we are beginning to make an appraisal of that prodigious human effort which won the war, we find that General Ferrié is entitled to high rank among the distinguished generals of France.

In awarding to General Ferrié their Medal, which bears the name of the illustrious philosopher and scientist, Benjamin Franklin, and in electing him to be an Honorary Member of their organization, the members of The Franklin Institute are paying to him the highest tribute which they can offer to a man of science. But this award contains another tribute—a recognition of the long-continued friendship between General Ferrié and his hosts of friends in the American Army and Navy and in civil life. He has coöperated with the United States Navy in time of peace and in time of war, and his numberless services to the American Expeditionary Forces and particularly to the Signal Corps and its scientific staff in France, will always be held in grateful remembrance.

It is fitting that I should at this time speak of that historic event in the annals of electrical communications when in October, 1915, speech was for the first time transmitted by telephone across the Atlantic Ocean. This was achieved as a result of work car-

ried out by that distinguished staff of scientists with whom I have the honour to be associated. The words were spoken into apparatus located at the Arlington radio station of the United States Navy, and they were heard at the Eiffel Tower by members of my staff whom I sent there for that purpose, by a representative of the United States Navy, and by General Ferrié and members of his staff. If it were not for the historic friendship which exists between the United States and France, and if it were not for the sympathetic consideration of General Ferrié towards Americans, and his devotion to science even during the darkest period of the war, this result could not have been achieved. To General Ferrié, therefore, goes the gratitude alike of the American and French scientists, for without his coöperation it could not be said that the first words ever spoken across the Atlantic Ocean passed between the two great Republics, the United States of America and France.

To-day, the Franklin Medal takes on new dignity and importance, for it has become a token of that historic friendship between France and America which was so firmly established by the mission of Benjamin Franklin to France, and which, having been again affirmed and hallowed by the ties of blood, can never be destroyed.

The President then said:

I desire, Colonel Dumont, before proceeding with the presentation of Franklin Medals—which is the business which has brought us together—to say to you and to our other guests that the Management of The Franklin Institute are highly sensible of the distinction added to this occasion by the presence of an official representative of the French Republic.

Sir, I have the honour, in the name of The Franklin Institute, to present to you, for transmission to your distinguished countryman, General G. Ferrié, The Franklin Medal and a Certificate of Honorary Membership in the Institute. This award with honorary membership is made to General Ferrié in recognition of his distinguished services to mankind rendered in the fields of pure and applied science. They are the highest honours in the gift of the Institute.

Colonel Dumont, in accepting the Medal and the Certificate of Honorary Membership said:

Monsieur President and Gentlemen: It would have given His

Excellency Monsieur Jusserand, the French Ambassador, the greatest pleasure to be present here to-day in order to receive, at your hands, in the name of France, The Franklin Medal and the Certificate of Honorary Membership in The Franklin Institute which you have awarded to General G. Ferrié, honours which you bestow only on eminent living scientists.

Unfortunately, the heavy duties of Monsieur Jusserand, heavier still as you may know, at the present time, have prevented him from coming to Philadelphia and he has entrusted me with the commission of acting on his behalf, during this ceremony.

Being neither a diplomat nor a scientist, I imagine that my being occasionally dressed up in the horizon blue uniform of France was one determining reason for my appointment, so that I do take a great deal of pride in representing on this occasion not only my dear old country at large, but in a quite special way the French Army, to which belongs the scientist you have chosen to honour. But at the same time how humble I feel amidst this distinguished company when reminded of what happened some thirty-six or thirty-seven years ago, when having, together with Ferrié, entered the competition in order to be admitted to our Polytechnic School, Ferrié was successful and myself hopelessly left behind the gates.

Now, this did not happen because he knew much more than myself or any one of us, about electricity—in fact, in 1886–1888 our professors had been so upset by these wonderful inventions, the telephone, the phonograph, others of the same kind, many of them, I must say, coming from this country, and displayed in Paris on the occasion of the special exhibition held in the old "Palace of Industry," that they had decided to suppress entirely for the time being, that part of the programme for admission.

Only ten years after he had been commissioned an officer in the Army, did Ferrié (as recalled by General John J. Carty) really begin to specialize in the work which was to bring him to preëminence, and gain for him the honours of to-day, so that he little thought, I am sure, in those old days I have taken the liberty of recalling, that, some time, he should sit night after night on the watch in this country, at Fort Meyer near Washington, anxiously trying to receive radio signals and messages from Paris.

What more can I say, after the tribute paid by General Carty, and in the presence of our mutual friend and brother in arms, Major General G. O. Squier, Chief Signal Officer of the U. S.

Army. Only this, maybe, because I know it to be true, General Ferrié is so devoted to science that these honours bestowed upon him, he does not consider them as merely the crowning of his past achievements but rather as an encouragement to keep in constant progress his research work, in close touch with his American friends, for the benefit not only of his country but of the entire world, because science having no limitations, ignores land boundaries.

America and France, both under the red, white and blue colors, enjoying the same ideals, the same eagerness for knowledge, the same love for liberty, have been in the past, and are now, so much in the heart of one another, that I hardly need conclude these few remarks in expressing my sentiment that this award is another token, after many others, of that real warm friendship which exists between our countries, our scientific associations, our public and private citizens, a friendship which like radio ignores time and space.

Dr. Arthur L. Day, Director of the Geophysical Laboratory of the Carnegie Institution of Washington, was then recognized and made the following statement concerning the work of Dr. A. A. Michelson:

It is our privilege to-day to bestow upon a distinguished physicist the highest award within the gift of this great Institute. The Franklin Medal, says the founder, shall be awarded "to those workers in physical science or technology . . . whose efforts have, in the judgment of the Institute, done most to advance a knowledge of physical science or its application." There are many other rewards of merit which are given annually by The Franklin Institute, but these commemorate a single preëminent accomplishment. The Franklin Medal alone confers recognition of a career of distinguished achievement in the advancement of our knowledge of physical science and its applications to the welfare of mankind. It is in this distinctive sense that the award of to-day attains to its highest significance, for among living physicists no career has been marked by greater singleness of purpose in the advancement of physical science and none has risen to such heights in the pursuit of that particular ideal of physics, the attainment of exact knowledge, as the one we commemorate to-day.

The most successful worker in the field of physical measurement expects to see results superseded through the development of

superior methods by another, or, as the science advances, to find that a working hypothesis requires revision or extension. In the forty-five years of nearly continuous research activity to which your attention is directed to-day there is hardly a slip or an unnecessary step in the continuous progress to accomplishments never surpassed. The modest note in the *American Journal of Science* for May, 1878, scarcely half a page in length, announcing a new method of measuring the velocity of light in which concave mirrors were dispensed with and the measured light-path might be of any length, is the same method in its essentials as that to be used by the same hand in the redetermination at Mt. Wilson this year. In the first attempt the measured light-path was a few metres, and the accuracy sought approached one part in 10,000, in the last the light-path is more than twenty miles and the accuracy sought, one part in five hundred thousand.

The importance of this constant, both for physics and astronomy, and the prevailing interest in the undulatory theory of light transmission, led to further study of its mechanism and to something very like the modern theory of relativity. The undulatory theory demanded a medium with certain properties (the ether) pervading all space. But the earth moves in space with a considerable velocity. It was therefore necessary to the determination of the absolute velocity of light to know whether the movement of the earth in the ether served to disturb its light transmitting power, and further, whether the velocity was the same when moving in the direction of the earth's motion or contrawise, or at right angles to it. This need for an apparatus to discover differences in the velocity of light along two paths perpendicular to each other gave us the interferometer which has since had a remarkable development and history. It has made it possible to use unchanging wave-lengths of light as our ultimate standards of length, and most small dimensions are now measured by its use.

A few evenings ago at the Carnegie Institution of Washington it was my privilege to listen to Doctor Michelson's own account of his discovery, in the laboratory of Professor Cornu, of the manner of interference of two beams of light meeting in different phase whereby interference bands or fringes are formed, alternately light and dark in monochromatic light, rainbow colored in white light. Professor Cornu was unwilling to accept this interpretation of the fringes without a demonstration and accordingly a primitive interferometer was arranged using white light. Such

a system is not easy to demonstrate satisfactorily under the best of conditions because of the great number of wave-lengths participating in the interference phenomenon and the consequent difficulty of adjustment of the apparatus, and so in the rather nerve-racking atmosphere of a demonstration before a skeptical master it happened that the fringes would not come. I suspect that the sympathy which was freely offered to the embarrassed student was about the last thing in the world which this particular student felt the need of just then, but be that as it may, a later demonstration was successful and brought with it appropriate recognition.

The method has since been employed to measure and compare national standards of length, to measure the rigidity of the earth, to determine the magnitude and the orbits of the satellites of Jupiter, the distance apart of double stars, and recently, in the most spectacular fashion, to determine the diameter of fixed stars where the greatest telescopes, as hitherto used, distinguish only point sources of light. Its accuracy in measurements of length, under favorable conditions, may reach one part in a million, probably surpassing that of any other instrument available to the physicist.

With a directness and a precision equally uncanny the subject of spectroscopy has been developed to a point hitherto undreamed of. The great ten-inch grating with a resolving power of 600,000 and the echelon spectroscope, which surpasses even this accomplishment perhaps seven or eightfold, are masterpieces of technical achievement no less than of ingenious analytical conception.

The determination of the rigidity of the earth and the establishment of a true elastic tidal movement of its solid surface might well stand alone and merit the recognition which The Franklin Institute accords to-day. Such outstanding figures in the physical world as Lord Kelvin and Sir George Darwin were able to wring from this overmastering problem, already several generations old, only so much as to conclude that the earth must have at least the rigidity of steel. With the tiny interferometer and two horizontal tubes 500 feet long and half filled with water Doctor Michelson determined, within less than one per cent., the magnitude, and even more accurately, the period, of the earth's solid tide. The newly recognized science of geophysics records no greater accomplishment than this.

For these services, Mr. President, in the advancement of "a knowledge of physical science" as provided in the deed of gift, I have the honour to present to you Dr. Albert Abraham Michelson, Doctor of Philosophy, of Science and of Laws, Professor of Physics of the University of Chicago, President of the National Academy of Sciences, recipient of the Nobel Prize for Physics (1907) and other awards, member of many learned societies, both American and foreign, to receive The Franklin Medal.

The President, in presenting The Franklin Medal and Certificate of Honorary Membership to Doctor Michelson, said:

I have the honour, in the name of The Franklin Institute, to present to you The Franklin Medal and a Certificate of Honorary Membership in the Institute. This award with honorary membership is made in recognition of your distinguished services to mankind in the field of science. They are the highest honours in the gift of the Institute.

Doctor Michelson, in accepting The Franklin Medal and Certificate of Honorary Membership, said:

Mr. President, Members of the Institute, Ladies and Gentlemen:

General Ferrié has over me the double advantage of being in Paris and of having Colonel Dumont acknowledge the honours that have been showered upon him.

For myself I can only assure you that words fail me, but nothing can exceed my appreciation of the distinguished honour done me. The Franklin Institute has risen in power and glory so that its reputation covers the whole wide world and my hope and faith is that it will so continue to progress, especially through the distinguished efforts of its able President and its efficient Secretary.

I may add that I do not claim any particular merit for the so-called distinguished service I have rendered, I doubt if any scientific man does his work to render distinguished service, I think he does it because it is good fun.

The President then recognized Major General George Owen Squier, Chief Signal Officer, U. S. Army, who read the paper, "The Scientific Applications of Radiotelegraphy," by General G. Ferrié (page 763).

The President then recognized Dr. A. A. Michelson, who read his paper on "Light Waves in Astronomy."

CORRESPONDENCE.

The Editor of the
JOURNAL OF THE FRANKLIN INSTITUTE,
Philadelphia, Pennsylvania.

The letter from Sir William H. Bragg, published in the November issue of your JOURNAL, has just come to my attention. In this letter he takes exception to the pertinence of the emphasis laid upon the theory of space groups in a recent discussion of the results of X-ray crystal analysis [JOUR. FRANK. INST., **195**, 183, 349, 531 (1923)]. Your correspondent seems to hold the view that the usefulness of this theory in crystal analysis is limited to the provision of a convenient (or perhaps confusing) "terminology" and that as a consequence the theory can contribute nothing of fundamental value to the study of atomic arrangement. I must dissent from this conclusion.

The essence of the methods which use the results of space group theory is that they aim to give consideration to all of the possible atomic arrangements for a crystal. The ultimate goal is not merely to discover a possible arrangement for the atoms in a crystal which will momentarily satisfy a particular observation, but to ascertain the only arrangement possible, having regard to the basic assumptions which underlie the interpretation of diffraction effects and the deduction of the space group theory. Whether this goal can be reached in any particular instance will depend upon the richness of the available experimental data; but even where it cannot be reached these methods indicate *all* of the other arrangements which remain experimentally indistinguishable and therefore possibly correct. Such knowledge cannot be supplied except by this theory itself or by geometrical considerations equivalent to its content. Both your correspondent and we who use space group theory are agreed in admitting X-ray diffractions as the only acceptable experimental criterion. It is for this reason inevitable that where enough data have been found to establish the structure uniquely (and resorcinol, cited by Professor Bragg, may be such an instance though the published data are inconclusive), the procedures used by him and the methods of crystal analysis using space group results will yield the same atomic arrangement. The point that requires emphasis, however, is this: That only by employing the theory of space groups or equivalent reasoning, can we ever be sure that there may not be a number of other structures in equally good agreement with the limited data then at our disposal.

Viewed in this light the issue resolves itself into a question of the relative scientific merits of two methods; one of these seeks

a possible, the other *the only possible*, solution to a problem. For those who feel that such a formal deduction of unique solutions is unnecessary, reference need only be made to the several cases listed in the previously mentioned discussion appearing in this JOURNAL, in which the older methods have failed to produce correct or necessarily correct crystal structures.

RALPH W. G. WYCKOFF.

Geophysical Laboratory,
Washington, D. C.
November 12, 1923.

Measuring Acceleration by Means of a Flame. K. PRYTZ. (*Jour. Phys. Radium*, June, 1923.)—If a closed lantern containing a burning candle be moved with a constant velocity, the flame retains its customary vertical position. However, upon moving the lantern from right to left horizontally, the axis of the flame at first tilts toward the left during the period of acceleration toward the left, and later, while the velocity is diminishing, it is inclined toward the right. In general the tip of the flame is displaced in the direction of the acceleration. When the lantern is let fall, the tip is displaced downward with respect to the wick and, in fact, the flame is shortened, as is confirmed by experiment.

A discussion of the theory leads to this relation, when the flame has a horizontal acceleration, $a = g \tan \beta$, where a is the acceleration to be measured, g the acceleration of gravity and β is the angle between a vertical line through the wick and the axis of the moving flame. The author suggests that the direction of the flame could be photographed on a film carried along with the lantern. The slight mass of the flame would permit it to follow aperiodically any changes in velocity.

A very interesting proposal for a new kind of dead reckoning is made. Along with the lantern let two automatic, photographic registering devices be mounted on a Cardan suspension in a ship. These should record the direction of the flame axis on two vertical planes at right angles to each other. Thus the direction and amount of the horizontal acceleration at all instants of the voyage could be deduced. Then the hodograph of the voyage could be constructed and from this, in turn, the velocity at each instant. Of course, from a knowledge of the starting-point of the vessel and of its velocities at all times, it is possible to determine its position at any hour. It is true that the pitching of the craft introduces vertical components of acceleration. This error would be reduced by locating the apparatus amidships. Moreover the rapid alternations in direction of these components cause them to have little effect on the final result. "As to knowing whether this method is practical or not, at this time I am unwilling to venture any opinion on this point." G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF RADIO SIGNAL FADING.[1]

By J. H. Dellinger, L. E. Whittemore and S. Kruse.

[ABSTRACT.]

WHEN radio first was used for long-distance communication it was noticed that signals were not transmitted as far during the day as during the night. It has also been observed that the direction from which radio waves are received at a given receiving station varies greatly from time to time, and that short wave signals may vary rapidly in intensity. On account of the dependence of these phenomena upon weather conditions, surroundings of the transmitting and receiving stations, and the nature of the country over which transmission occurs, it is only by a statistical study that reliable conclusions regarding their nature can be obtained.

During the summer and fall of 1920 and the spring of 1921, a series of tests was conducted by the Bureau of Standards in coöperation with the American Radio Relay League. During these tests, signals were transmitted by from five to ten radio stations in succession, test schedules having been arranged in advance for certain specified nights. The signals were received simultaneously by about one hundred receiving stations, whose locations cover the northeastern part of the United States. These tests have confirmed, in a statistical way, what had previously been little more than impressions received by operators and experimenters in the course of receiving radio messages.

Signals from a given transmitting station may be received with violent fading by some receiving stations and simultaneously with very little fading by others. As a result of the statistical analysis of over 5000 records secured during the tests, tables have been prepared giving suggested relationships between the fading and intensity of signals and the prevalence of strays and the weather conditions which existed at the times of transmission. For example, it was observed that general cloudiness over the region between the transmitting and receiving stations has a tendency to produce severe fading.

* Communicated by the Director.

[1] Scientific Papers, No. 476, price ten cents.

As an explanation of the phenomena observed it may be considered that the transmission of radio waves during the daytime is largely along the surface of the earth, that part of the waves which is radiated upward being absorbed by the atmosphere. Night transmission, however, especially for great distances and using short wave-lengths, is probably by means of waves transmitted along the Heaviside surface, a highly conducting layer at a height of about sixty miles above the surface of the earth. Waves at night are thus free from the absorption encountered in the daytime, but are subject to the great variations caused by irregularities of the ionized air at or near the Heaviside surface. The transmission along this surface with relatively little absorption may thus account for the long distances covered at night, while the variations in such absorption as is present probably account for the fading.

DETECTOR FOR WATER VAPOR IN CLOSED PIPES.[3]

By E. R. Weaver and P. G. Ledig.

[ABSTRACT.]

A SIMPLE device is described for determining the approximate concentration of water vapor in a gas. A glass tube is coated with platinum and the coating divided by etching into two electrodes. Platinum wires, sealed through the glass, connect the electrodes to a measuring circuit. The resistance to alternating current of a thin film of a hygroscopic electrolyte bridging the gap between the electrodes is used as the measure of the water vapor in the atmosphere with which the film is in contact. Sulphuric and phosphoric acids and various hygroscopic salts can be used in forming the conducting film. The detector is simple, rugged, and easily adapted for use in high-pressure piping and other situations in which the determination of water vapor is usually attended with difficulty.

Quantitative determinations with a single detector are possible over only a small range of concentration of water vapor, and must be made under rather carefully controlled conditions. The location of the sensitive range depends upon the hygroscopic substance employed.

Laboratory experiments showing the reliability, method of application and limitations of the device are described.

[3] Technologic Papers, No. 242, price five cents.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

QUANTUM THEORY OF PHOTOGRAPHIC EXPOSURE, III.[1]

By L. Silberstein.

In this paper account is taken of the absolute energy values (determined experimentally) of the exposure used in the experiments described in the previous papers. It is shown that in the emulsion used not more than one ten-thousandth, and probably not more than about one hundred-thousandth, of the area of a grain is sensitive to light, *i.e.*, made developable on being hit by a single light dart. The probable explanation of this is that only a small minority of all the darts cause developability by ejecting photo-electrons, a result in agreement with photo-electric experiments of Elster and Greitel and Pohl and Pringsheim. Previously it has been assumed that, at any rate for equal-sized grains, the small area of the grain which is especially sensitive is all in a lump, but now the assumption is made that the grain contains a number of separate specially sensitive spots distributed among the individual grains haphazardly, the sufficient condition for grain developability being that at least one of its spots is hit by at least one light dart of a wave-length less than the critical wave-length. It is shown that the main results previously obtained are not altered very much by this assumption. Starting with the elementary equation

$$k = N\,(1 - e^{-n\epsilon a})$$

where k = number of grains changed out of the total, N, n = number of quanta incident, a = area of single grain and e = fraction of area a which is specially sensitive, the author deduces the integral or "density" formula for a certain type of emulsion. Comparison with experimental results recently obtained with X-rays shows an excellent agreement, all the differences between the theoretical and observed values being well within the limits of experimental error.

* Communicated by the Director.

[1] Communication No. 173 from the Research Laboratory of the Eastman Kodak Company and published in *Phil. Mag.*, May, 1923, p. 1062.

NOTE ON THE INFLUENCE OF CRYSTAL HABIT ON THE PHOTOCHEMICAL DECOMPOSITION IN SILVER BROMIDE CRYSTALS.[2]

By S. E. Sheppard and A. P. H. Trivelli.

IT IS noted that while the visible photochemical decomposition has in common with the initiation of development the property of commencing at isolated points, its further increase may be a relatively orderly process, vectorial in character, and oriented according to definite directions in the crystal. Although the accretion of the photoproduct proceeds mainly by discontinuous increments, the accretion is neither uniform, nor purely haphazard, but radiates along the lines of more rapid growth.

THE CRYSTALLINE STRUCTURE OF SILVER IODIDE.[3]

By R. B. Wilsey.

IN a preliminary note (*Phil. Mag.*, **42**, 262, 1921) the author reported the observance of the diamond cubic type of structure for silver iodide by the X-ray powder crystal method. The present paper reports in detail the results of an X-ray examination of a number of samples of silver iodide, some of which showed only the diamond cubic structure, while others showed a mixture of the cubic and hexagonal structures in which, as a rule, the hexagonal structure predominated. The deduction of the diamond cubic structure for silver iodide has been criticized by Aminoff and by Wyckoff, who assert that the powder method does not distinguish between the diamond, cubic, and hexagonal structures, and state that their own observations, by the Laue method, show the hexagonal form to be the true structure for silver iodide. The author points out that while the powdered crystal diffraction patterns for the two structures have many lines in common, each has lines not possessed by others, so that the powder method should distinguish between the two provided satisfactory photographs can be obtained. The powder photographs obtained in the present study show clearly the two structures, each distinguishable by its own characteristic lines. It is

[2] Communication No. 182 from the Research Laboratory of the Eastman Kodak Company and published in *Photo. J.*, July, 1923, p. 334.

[3] Communication No. 184 from the Research Laboratory of the Eastman Kodak Company and published in *Phil. Mag.*, July, 1923, p. 487.

concluded that the disagreement among different observers is due rather to the samples examined than to the methods of analysis employed. In addition, the lattice constants of silver chloride, silver bromide and metallic silver were remeasured. The results are summarized in the following table:

Crystal.	Lattice structure.	Side of elementary unit of structure in Ångstroms.	Distance apart of nearest atomic centres.
Silver chloride	Simple cubic Na-Cl type	5.540	2.770
Silver bromide	Simple cubic Na-Cl type	5.768	2.884
Silver iodide	Diamond cubic Zn-S type	6.493	2.812
Silver iodide	Hexagonal Zn-O type	4.593 (c/a = 1.633)	2.813
Metallic silver	Face centred cubic	4.078	2.884

A LABORATORY FRACTIONATING COLUMN.[4]

By H. T. Clarke and E. J. Rahrs.

A FRACTIONATING column constructed entirely of glass tubing arranged with suitable indentations. A cooling unit at the head provides for the desired amount of return flow. Experimental figures show that about half of each component of an equal mixture of benzene and toluene can be obtained nearly pure on the first distillation.

DEVELOPMENT OF MOTION PICTURE FILM BY THE REEL AND TANK SYSTEM.[5]

By J. I. Crabtree.

THIS article deals exhaustively with the handling of motion picture film by the reel and tank systems during the operations of developing, fixing, washing, and drying. The information is classified as follows:

[4] Communication No. 167 from the Research Laboratory of the Eastman Kodak Company and published in *Ind. Eng. Chem.*, April, 1923, p. 349.

[5] Communication No. 187 from the Research Laboratory of the Eastman Kodak Company and published in *Trans. Soc. Mot. Pict. Eng.*, May, 1923, p. 163.

(1) *Apparatus.*—The various types of racks, reels, tanks, and troughs are described and illustrated, the layout of a typical development room is given and the materials suitable for construction of such apparatus are discussed.

(2) *Chemical Solutions.*—Developing and fixing solutions are discussed in respect to their preparation, photographic properties, life, and methods of revival. Formulas, which fulfill the various requirements, are given.

(3) *Manipulative Details.*—Detailed instructions are given for dealing with various types of motion picture film, together with the control tests and variations in treatment under different conditions.

(4) *Troubles.*—Troubles which are commonly met with in each process are listed with suggestions for their prevention and removal.

NOTE ON THE THEORY OF PHOTOGRAPHIC SENSITIVITY.*

By S. E. Sheppard and E. P. Wightman.

THE theory that the latent image consists of colloidal silver and that there are, also, present in the grain, prior to exposure, colloidal silver specks, which form development centres by exposure, are discussed, and experimental evidence is given that such preëxistent specks do occur and that they are distributed both inside the grain as well as on the surface. It is supposed that the first action of the light is to release a photo-electron from the colloid silver speck, that the free electron, having a free kinetic energy $\frac{1}{2}mv^2 = h\nu$, where ν is the frequency of the active light, is then able to enter the silver ion, forming a neutral silver atom, while the unneutralized bromide ion loses an electron. This chain reaction, analogous to that suggested by Bodenstein, for the action of light on hydrogen and chlorine, would go on to a limiting state, depending on the initial energy of the photo-electron, but producing a nucleus large enough to initiate development for a developer of given reduction potential.

* Communication No. 185 from the Research Laboratory of the Eastman Kodak Company and published in *Science*, August 3, 1923, pp. 89–91.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

NUTRITIVE VALUE OF MIXTURES OF PROTEINS FROM CORN AND VARIOUS CONCENTRATES.[1]

By D. Breese Jones, A. J. Finks and Carl O. Johns.

[ABSTRACT.]

MIXTURES consisting of 25 parts of tomato-seed press cake, soy-bean flour, or peanut flour, and 75 parts of yellow corn-meal, which contained from 12 to 15 per cent. of protein, furnished proteins adequate for the normal growth of albino rats when incorporated in a diet made nutritionally adequate with respect to the dietary factors other than protein.

A mixture of equal parts of corn-meal and coconut-meal at a protein level of 12 per cent. was efficient for growth at the normal rate. The growth was somewhat subnormal when the proportion of protein was reduced to 9.6 per cent.

From experiments in which the mixtures of corn-meal and concentrates furnished 7.2 per cent. of protein, it is concluded, from the gain in weight per gram of protein consumed, that the comparative growth-promoting value of the proteins of tomato seed, peanut, and soy bean, as a supplement to corn proteins, is in the order: Soy bean, peanut, and tomato seed.

FLUORO-ACETYL DERIVATIVES OF SUGARS. II. OPTICAL ROTATION AND ATOMIC DIMENSION.[2]

By D. H. Brauns.

[ABSTRACT.]

IN comparing the optical rotations of monohalogen acetyl derivatives of glucose, cellose, xylose and fructose, the differences F-Cl, Cl-Br, and Br-I are found to be approximately proportional to the differences in atomic diameter recorded by Bragg. It is remarkable that this simple relation holds for the specific but not for the molecular rotation. The method of preparation, properties, and analyses of fluorotetra-acetyl-fructose and bromotetra-acetyl-fructose are given.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Agr. Res.*, **24** (June 16, 1923): 971.

[2] Published in *J. Am. Chem. Soc.*, **45** (Oct., 1923): 2381.

IS GASEOUS NITROGEN A PRODUCT OF SEEDLING METABOLISM?[3]

By Jehiel Davidson.

[ABSTRACT.]

WHEAT seedlings and cow-pea seedlings were grown in Kjeldahl flasks under sterile and non-sterile conditions. The results showed that no nitrogen in gaseous form is lost in the process of germination and in the early life of the seedlings as an inherent function of their metabolic processes.

THE RELATION OF THE OXIDIZABILITY VALUE AND THE AMINO AND AMMONIA NITROGEN CONTENT TO THE QUALITY OF CREAM AND BUTTER.[4]

By L. W. Ferris.

[ABSTRACT.]

AN examination of representative samples of cream and butter from thirteen creameries showed that the second-grade cream contained a higher percentage of the total nitrogen present as amino nitrogen and ammonia than the first-grade cream. This value averaged from 1.6 to 9.6 on cream producing first-grade butter and 8.1 to 12.6 on cream producing second-grade butter. The results on the corresponding butters varied from 0.8 to 6.3 for the first-grade and from 4.7 to 6.7 for the second-grade samples. The butter from the cream containing the smaller amounts of amino nitrogen and ammonia as per cent. of the total nitrogen scored from 93 to 94, while the butter from the cream having the higher value showed a general decrease in score. The oxidizability value varied from 0.4 to 6.7 on the first-grade butter and from 3.4 to 8.8 on the second-grade butter, being higher, in general, on samples having the lower scores. Eleven authentic samples of fresh milk from individual cows gave values for amino nitrogen and ammonia as per cent. of the total nitrogen varying from 2.2 to 3.6.

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[3] Published in *Botan. Gaz.*, 76 (Sept., 1923): 95.

[4] Published in *J. Dairy Sci.*, 6 (Sept., 1923): 412.

FURFURAL FROM CORNCOBS.[1]

III—EFFECT OF CATALYSTS ON FURFURAL YIELD IN THE STEAM DIGESTION PROCESS.

By Frederick B. LaForge and Gerald H. Mains.

[ABSTRACT.]

LABORATORY experiments were made to determine the effect of using small quantities of catalysts. With hydrochloric, sulphuric, and phosphoric acids a marked increase in the yield of furfural was obtained when the quantities of acid added were sufficient to neutralize the natural base of the cobs. Larger quantities did not give a proportionate increase. The effect of the mineral acids is probably due largely to the organic acids, especially formic, which are liberated. Direct addition of formic acid produced a somewhat greater increase in yield than did the mineral acids. Sulphurous acid gave results comparable with those obtained by formic acid, indicating that the presence of a reducing agent increases the yield. From an economic standpoint the sulphuric and sulphurous acid catalysts seem to offer the greatest promise.

Semi-commercial runs using the sulphuric acid catalyst gave furfural yields of about 9 per cent., 50 per cent. higher than those obtained in steam digestion without catalysts. The small quantity of acid used does not require neutralization, and there is no increase in steam requirement for the process. Hence the catalytic process offers a decided commercial advantage.

The Electrical Resistance to Currents of High Frequency Shown by Wires that are Enclosed in Conducting Envelopes. F. TRAUTMANN. (*Ann. d. Physik*, 1923, No. 17.)—The wires investigated were either stretched along the axes of glass tubes, filled with electrolytes, or were covered with a layer of another metal. Wave-lengths from 50 to 1800 metres were used. It should be remembered that with electric waves of high frequency the "Skin Effect" is much in evidence, that is, the current is mostly in the outer portions of the wire, while the core of the wire does little in the way of conducting current.

"Thin layers of small conductivity (electrolytes) produce considerable increases of resistance only when short waves are used, but thick layers have a bad effect even with longer wave-lengths." A case is cited (the diameter of the wire seems to be given incorrectly)

[1] Published in *Ind. Eng. Chem.*, 15 (Oct., 1923): 1057.

where a thickness of .82 centimetre of concentrated NaCl solution around the wire caused the apparent resistance of the latter to become 5.46 times as great as the resistance had previously been for the naked wire with the same wave-length of 50 metres. When the thickness of the electrolyte was .18 centimetre the increase of resistance amounted to no more than 7.2 per cent.

Brass wires, covered with the better conductor, copper, show a better conductivity than without the copper. There is nothing odd in this, since the oscillating currents are largely in the outermost layer.

Interesting observations were made with iron and steel wire covered with a layer of copper. "The transfer of the main conductivity to the covering was in evidence even with thin layers of it. For a range of thickness of the copper the resistance of the composite wire was only slightly dependent on the wave-length used." It would thus seem possible to select ferromagnetic wire of appropriate quality and to plate with a good conductor with the result that the wire thus prepared should be much larger than the wire usually counted to be free of the skin-effect and at the same time should have a practically constant resistance for a considerable range of wave-lengths.

The author suggests that much copper can be saved by the use of iron or steel wire, copper plated, that is designed so as to have the same resistance as solid copper wire. For a wave-length of 50 metres a solid copper wire of .1025 centimetre radius has a resistance of .109 ohm per metre. The same resistance is got by using an iron wire of radius .0985 centimetre coated with copper .004 centimetre in thickness.

Copper wire plated with iron shows a great increase of resistance with frequency. Moreover, for short wave-lengths there is an enormous increase of resistance produced by a very small increase in the thickness of the iron. G. F. S.

A New and Simple Law in the Geometrical Optics of Lenses. E. SCHWARCZ. (*Zeit. f. Phys.*, Vol. 16, July, 1923.)—For central rays traversing a thin lens the following relation is deduced: The locus of the images of a fixed luminous point, which are produced by a lens translated along its optical axis, is a hyperbola. If the origin of coördinates is at the intersection of the optical axis with a line perpendicular to it and at a distance of twice the focal length from the object, then the hyperbola is asymptotic to the optical axis and to a second line passing through the origin. This line makes with the axis an angle determined by the fact that its tangent is the distance of the object from the axis divided by the focal length of the lens. For converging lenses the hyperbolic locus of real images lies on the side of the lens away from the object, while the locus for virtual images is on the same side. The two parts are, of course, the branches of the same hyperbola. G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, November 21, 1923.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1923.

MR. W. C. L. EGLIN, Vice-president, *in the Chair.*

The Board of Managers submitted their report. The report recorded the election of the following Life Member:

Henry Clay Gibson, Esq.,
Treasurer, Bank of North America and Trust Company,
Philadelphia, Pennsylvania;

the following Resident Members:

Dr. Arthur Howell Gerhard,
Manufacturer and Instructor in Medicine,
1615 North Delaware Avenue,
Philadelphia, Pennsylvania.

Irvin Kline Giles, Esq.,
3144 Passyunk Avenue,
Philadelphia, Pennsylvania.

Dr. Jessie A. Rodman,
Teacher of Physics,
81 High Street, Germantown,
Philadelphia, Pennsylvania.

Dr. Frederick Hollister Safford,
Professor of Mathematics,
College Hall, University of Pennsylvania,
Philadelphia, Pennsylvania.

Alfred J. Vollrath, Esq.,
Vice-president, Baker Perkins Company,
Philadelphia, Pennsylvania.

Howard Waldo Welles, Esq.,
Mechanical Engineer, Commercial Truck Company,
Philadelphia, Pennsylvania;

the following Non-resident Members:

Dr. Ellwood Hendrick,
Chemist and Author,
139 East Fortieth Street,
New York City, New York.

Dr. Louis Alexander Parsons,
Professor of Physics, Gettysburg College,
Gettysburg, Pennsylvania.

Francis du Pont Thomson, Esq.,
Engineer,
514 Yale Avenue,
Youngstown, Ohio;

the following Associate Member:

Charles Frederick Kellers, Esq.,
Student, Union College,
Schenectady, New York.

and additions to the library by gift, 23 volumes, 112 pamphlets, and by purchase, 53 volumes.

The Chairman recognized Mr. Fulweiler, who offered the following resolution, which was duly seconded and passed unanimously:

"*Resolved*, That a committee of three be appointed to nominate Officers and Managers for the year 1924."

The Chairman then announced that the next business of the meeting would be the presentation of the Elliott Cresson Medal to Albert Kingsbury, for his invention of the "Kingsbury Thrust Bearing," and recognized Mr. W. H. Fulweiler, Chairman of the Science and Arts Committee.

Mr. Fulweiler said: "Mr. President, Members of The Franklin Institute, Ladies and Gentlemen:

"As a nation, we have been criticized for not developing to a greater extent our resources in water power. This, however, is probably due to our economic conditions where coal has been relatively cheap and capital relatively dear.

"In the design and development of apparatus, however, our engineers have been in the forefront, and the subject of this award has to do with the development of an important feature in the construction of large turbine units. One of the factors which has appeared to limit the construction of larger turbines was the difficulty of properly lubricating the thrust bearings which were called upon with the enlargement of the apparatus to carry tremendous loads.

"Various devices were employed to secure the necessary lubrication, among these being the supplying of oil under very high pressure but with any failure of the oil supply the unit naturally had to be shut down. In Mr. Kingsbury's invention the bearing is composed of a solid upper plate supported by a number of segments or shoes. The whole bearing is immersed in a bath of oil. In order to insure the entrance of the oil between the bearing surface the thrust pressure is not transmitted to the separate shoes in the centre of their areas but slightly eccentrically, so that as the upper plate revolves a wedge-shaped film of oil is continuously dragged between the bearing surfaces. In this manner, ample and adequate lubrication is always secured without the dependence upon external auxiliary such as oil pressure pumps, etc.

"This invention has been applied not only to thrust bearings on large turbine units, but also to ship propellers and a large number of our destroyers are equipped with this type of bearing.

"Your Committee on Science and the Arts, through a sub-committee, has very carefully examined this invention, and their report concludes as follows:

"'In consideration of marked excellence of design and construction and signal success in eliminating end thrust troubles from modern high-power turbine machinery, The Franklin Institute awards its Elliott Cresson Medal to Albert Kingsbury, Esq., of Philadelphia, Pennsylvania, for his Thrust Bearing.'

"Mr. President, I have the honour to present to you Mr. Albert Kingsbury, of Philadelphia, to receive the Elliott Cresson Medal for his invention of the Thrust Bearing."

The Chairman presented the medal and accompanying documents to Mr. Kingsbury, who expressed his appreciation of the high honour conferred upon him by the Institute.

The Chairman also announced that the Edward Longstreth Medal would be presented to Harry S. Parks for his invention of the "Pnumercator Tank and Draft Gauge" and again recognized Mr. Fulweiler.

Mr. Fulweiler said: "Mr. President, Members of The Franklin Institute, Ladies and Gentlemen:

"One of the most important developments in the operation of vessels has been the use of oil fuel. This has been especially important for naval vessels and for the faster passenger ships. The great advantage of oil fuel is the fact that it requires less space for its storage, thus permitting greater cruising radius or greater cargo space at the same time reducing the fire room force.

"Another reason why oil fuel may be so advantageously used is the fact that it can be stored in almost any available space, for instance, double bottoms may be used or one tank may be placed above another. It is necessary, however, to have means to measure the contents of these tanks and it must be evident that frequently the tanks must be placed in relatively inaccessible positions. The invention of Mr. Parks has to do with the most ingenious method which he has devised for measuring the contents of tanks which may be in any position. It is only necessary that the actual measuring apparatus which consists of a mercury gauge supplied with compressed air be connected to the tank by means of a thin copper tube not so large as a lead pencil.

"In the operation of the device, air is passed into the apparatus until the hydrostatic head due to the material in the tank is balanced against the mercury gauge, thus by means of appropriate calibrations the contents of the tanks may be read directly.

"It is natural that such an ingenious device would find a number of applications, among these might be mentioned its use in determining the draft of vessels and by combining the draft forward and aft with appropriate calibration of the gauge, the dead-weight tonnage of the vessel may be determined at any time or again by determining the draft at two points located in a horizontal plane, the trim of the vessel can be determined. This device has also been applied to the measurement of oil in numerous tanks, all of the readings being made from a central point.

"Your Committee on Science and the Arts has very carefully investigated Mr. Parks' invention and in consideration of soundness in design, excellence of construction, and its proved value as a practical indicating device for the distant measurement of liquid pressure, The Franklin Institute awards its Edward Longstreth Medal to Harry S. Parks, Esq., of Philadelphia, Pennsylvania, for his Pnumercator Tank and Draft Gauge.

"Mr. President, I have the honour to present Mr. Harry S. Parks to receive the Edward Longstreth Medal for his invention of the Pnumercator Tank and Draft Gauge."

The Chairman presented the medal and accompanying documents to Mr. Parks, who thanked the Institute for the honour conferred upon him.

The Chairman then introduced Rear-Admiral William A. Moffet, U. S. N., Chief, Bureau of Aeronautics, Navy Department, Washington, D. C., who presented the paper of the evening on the "ZR-1, the First Helium-filled Dirigible."

The speaker referred to the cessation of airship building abroad and to the reviving of this art by the American Navy, which constructed the ZR-1, in which is used helium, a non-combustible and non-explosive gas. By use of lantern slides, he pointed out the main structural members of this airship, the arrangement of the gas bags and the location of the motors. He said that naval constructors had turned their hands to airship building, and were pioneering for a new industry and a new commercial era in aeronautics. He further referred to the airship as a new factor in world commerce, and by use of charts pointed out possible airship routes which would greatly aid in speeding up communications and cutting down distances. He also emphasized the great importance and value of the airship as a naval unit.

After a brief discussion, a rising vote of thanks was extended to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, November 7, 1923.)

HALL OF THE INSTITUTE,
PHILADELPHIA, November 7, 1923.

MR. W. H. FULWEILER, *in the Chair.*

The following report was presented for first reading:

No. 2792: Mills-Packard Patent Water-cooled Chambers for the Manufacture of Sulphuric Acid.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, November 14, 1923.)

RESIDENT MEMBERS.

DR. ARTHUR HOWELL GERHARD, Manufacturer and Instructor in Medicine, 1615 North Delaware Avenue, Philadelphia, Pennsylvania.

MR. HENRY CLAY GIBSON, Treasurer, Bank of North America and Trust Company, Philadelphia, Pennsylvania.

MR. IRVIN KLINE GILES, in care of Atlantic Refining Company, Philadelphia, Pennsylvania.

DR. JESSIE A. RODMAN, Teacher of Physics, 81 High Street, Germantown, Philadelphia, Pennsylvania.

DR. FREDERICK HOLLISTER SAFFORD, Professor of Mathematics, College Hall, University of Pennsylvania, Philadelphia, Pennsylvania.

MR. ALFRED J. VOLLRATH, Vice-president, Baker Perkins Company, 661 Drexel Building, Philadelphia, Pennsylvania.

MR. HOWARD W. WELLES, Mechanical Engineer, Commercial Truck Company, Philadelphia, Pennsylvania.

NON-RESIDENT MEMBERS.

MR. WILLIAM DUBILIER, President, Dubilier Condenser and Radio Corporation, 48 West Fourth Street, New York City, New York.

DR. ELLWOOD HENDRICK, Chemist and Author, 139 East Fortieth Street, New York City, New York.

DR. LOUIS ALEXANDER PARSONS, Professor of Physics, Gettysburg College, Gettysburg, Pennsylvania.

MR. IOWA SMITH, Commercial Engineer, International Telephone Company, Clinton Building, Columbus, Ohio.

MR. FRANCIS DU PONT THOMSON, Engineer, 514 Yale Avenue, Youngstown, Ohio.

ASSOCIATE MEMBERS.

MR. CHARLES FREDERICK KELLERS, Student, Union College, Schenectady, New York.

CHANGES OF ADDRESS.

MR. C. E. BENNETT, Electrical Engineer, Georgia Railway and Power Company, Atlanta, Georgia.

MR. ARTHUR BLACKBURN, 405 Hollen Road (Cedarcroft), Baltimore, Maryland.

MR. ERNEST H. DAVIS, 901 Vine Avenue, Williamsport, Pennsylvania.

MR. FRANK GITTELSON, 1017 Spruce Street, Philadelphia, Pennsylvania.

PROF. MOSES GOMBERG, 712 Onandaga Street, Ann Arbor, Michigan.

MR. EDWARD HEITMAN, 630 Bergen Avenue, Jersey City, New Jersey.

MR. F. E. IVES, 1726 North Park Avenue, Philadelphia, Pennsylvania.

DR. ENOCH KARRER, National Lamp Works of General Electric Company, Wire Division, Cleveland, Ohio.

MR. LEONARD KEBLER, 21 Ridge Road, Bronxville, New York.

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BOOK REVIEWS.

TECHNICAL METHODS IN ANALYSIS OF METALLURGICAL AND ALLIED PRODUCTS. By Wilfred W. Scott, Sc.D., Colorado School of Mines. xxviii–875 pages, 8vo. 150 illustrations and 2 colored plates. New York, D. Van Nostrand Company, 1923. Price, $6 net.

In preparing the present work the author has had in mind the combining of a manual for students in advanced courses and a reference for the practising metallurgist. With eight years of experience as a teacher of chemistry and twelve years as a professional metallurgist, the author is well equipped to

meet these two tasks, nevertheless, specialism has gone so far in chemistry, as in every other science, that collaborators have been necessary. These collaborators are Doctor Van Tuyl, Doctor Palmer and Doctor Low, colleagues of the author, and Doctor Hale of the Department of Water Supply, Gas and Fuel of New York City. The table of contents covers twenty-one pages, the items being set forth in unusually extended form. It is a question if this is necessary. A good index is far more serviceable. A book of this character will find its largest use as a reference, and the quick finding of a given item is what the user desires. A full list of illustrations is also given. This also seems unnecessary. It would probably be regarded as inadvisable to include the illustrations in the index, but it seems to the reviewer that such an arrangement would be as satisfactory as the separate list, and even more satisfactory than a list in which the arrangement is by order of pages. In this latter arrangement one has to know where the illustration is in order to turn to it quickly. Indeed, a consultation of the index shows that the illustrations are, at least in some cases, included.

The book presents a great variety of processes. The specific descriptions are preceded by a comprehensive chapter on analytic methods, including instruction in the principal phases of stoichiometry. A justifiable note is given to the student that it is usually unnecessary to carry calculations beyond the second decimal place. The practice of carrying to four or five places has, indeed, disappeared. Older chemists can remember the absurd practice, especially in vogue among German chemists, in which the data in water analysis were expressed to four or five decimal places, and this when the atomic weights were not accurately determined beyond the first decimal.

The work is rather liberally illustrated, but in a number of cases these are merely cuts from catalogues. It is doubtful if either student or practising analyst gets any benefit or finds any interest in a picture of a drying oven or an analytic balance. Actual use of the apparatus is the method of acquiring a knowledge thereof. The analytic balance illustrated is one furnished by a special supply company, but many analysts will from necessity or choice use other types. The same is true of the picture of the set of weights. It means nothing to anyone. There are two colored plates, one of arsenic stains under Gutzeit's method, the other of spectra, the latter by a typographical error being entitled "Emmissions-spectra," which gives rise to a suspicion that it was "made in Germany." In these cases also, the reviewer is of the opinion that the expense involved in such printing is not necessary. Students should be made familiar with spectra and the whole range of color reactions by actual experience. A few hours spent with a good spectroscope and carefully selected substances are more useful than the best plates that can be produced.

Doctor Scott's book, however, does not suffer in value and usefulness by these accessory matters. He has combined in it a very large amount of information in the field of metallurgical analysis. In this field the time-element has come to be of great importance. Formerly, the analysis of ores and metals was mostly the work of those regularly engaged in general practice. The days when the chemist was toxicologist, sanitarian and metallurgist are gone, and the large industrial establishments have their own laboratories. Gone also are the days when twenty-four or forty-eight hours could be allowed for

a determination of sulphur in a coal or copper in an ore. To-day rapid methods are needed. The introduction of analyzed reagents and standard methods has simplified and speeded up the works-laboratory as well as that of the professional analyst. The book in hand will be of great aid to both classes of chemists. HENRY LEFFMANN.

L'INDUSTRIE DU GAZ. DISTILLATION DE LA HOUILLE. By René Masse and Auguste Baril. 295 pages, 77 illustrations, small 8vo. Paris, Gauthier-Villars et Cie., 1923. Price, in paper, 20 Francs, net.

TRAITEMENT DES PRODUITS ET SOUS-PRODUITS. By the same authors. 307 pages, 115 illustrations, small 8vo. By the same publishers, 1923. Price, paper bound, 20 Francs, net.

These volumes are part of the second series of the Encyclopédie Léauté, conducted by André Léauté, which is intended to present compact, up-to-date information on basic chemical industries. The two volumes comprise the whole field of chemical engineering in regard to the products of the distillation of coal. They contain a very large amount of information and are evidently the work of experienced gas engineers. The French word "houille" is, according to Littré, of unknown etymology; it has recently come into prominence in connection with the expressive French term for water power "houille blanche," "white coal." The first of the two volumes is devoted to the methods of distilling coal for obtaining illuminating gas. The descriptive text is preceded by a short history of illumination, and specifically of the beginning of the use of gaseous materials. We are not surprised that the authors claim the first step in this direction to have been made by a Frenchman, but they seem to make out a case for Lebon, who in 1787 experimented on the distillation of sawdust on a very small scale. His early death prevented extended development of his views. Reference is, of course, made to the part taken by Murdoch in the practical application of coal-gas.

The question of the possible ousting of gas lighting by electric lighting is discussed briefly. The authors are enthusiastic in their view that no such danger impends at present. "Il n'en est rien," "nothing doing," is their verdict. The matter is hardly to be dismissed so easily. It does not follow, however, that if gas lighting should become uncommon, that the gas-making industry would suffer serious injury. Modern invention has shown its very useful adaptation to fields entirely outside of lighting. Cooking by gas, and limited heating of rooms has been long in vogue, and as the coal problem becomes more and more serious, as it is almost sure to do, the usefulness of gaseous fuel will be enhanced. Gas engineers and experts in public utilities should turn actively towards the problem of adapting ordinary gas to general house heating. At present the so-called stoves for room heating are wasteful and unsanitary. It seems entirely probable that a careful study of the subject will result in the invention of stoves which are economical, safe and ornamental. If the illuminating phase is entirely surrendered to the electric company, it will be possible to avoid the cost of enriching the low candle-power products, such as pure water gas, and to serve the gas as made, but in such case a stench must be inserted to protect against accidental escape. One of the United States scientific bureaus has been giving a great deal of attention

to the question of suitable stenches. Messrs. Masse and Baril are of the opinion that electric and gas companies should combine, a thought with which most persons will agree.

Valuable information is given concerning the distribution of gas-coal in the world. The United States is one of the most abundantly supplied. The authors remark that the United States has been wasting its resources in this respect—as indeed, it has been doing in many other respects—but is now proceeding more carefully. Some note is made of the destruction of the mines in the part of France occupied by the Germans. The figures showing the rehabilitation of these are encouraging. In January, 1919, only about 1500 tons (presumably metric tons) were produced, but in January, 1923, considerable over 800,000 tons.

The two books cover together all the important principles involved in gas engineering and by-product handling, and are well worth the attention of engineers in that field. HENRY LEFFMANN.

VALENCE AND THE STRUCTURE OF ATOMS AND MOLECULES. By Gilbert Newton Lewis, University of California. American Chemical Society Monograph Series. 172 pages, 27 illustrations, 8vo. New York, Chemical Catalog Company, Inc., 1923. Price, $3 net.

This is a profound, but clearly set forth, study of the most recent developments in the field of atomic and molecular physical chemistry. The author expresses in the preface that the data, or at least the inferences here presented, belong to the ephemeral literature of the science. If this is true, and the reviewer is not inclined to dispute it, the same may be said for all inferences in all sciences. The progress of knowledge may be compared to the ascending of a spiral staircase. The observer stops at a certain point and views the landscape. His view is bounded by a horizon either far away or limited by hills or forest. He travels on and soon arrives at the opposite point of the circle. The whole view has changed. Nature does not present the same aspects and he revises his inferences. Still travelling he arrives at the same point of the circle from which he started, but a little higher up. A more distant horizon is observed. The older inferences return but with modifications. Thus science moves. Ideas are accepted; theories and hypotheses become dominant; the competence of teachers and workers is tested by the extent to which they accept the dogmas. Research moves on, theories and hypotheses are thrown aside, but later rescued, modified and again set up for worship. Professor Lewis seems to hold the same thought but believes in a more rapid change, comparing the progress of science to the views in a kaleidoscope. He has been active in research in the field to which this work is devoted and is competent to speak on every phase of it. He has given chemists an interesting and valuable condensation of the recent literature.

The opening chapter is appropriately a historical summary, beginning with Dalton's theory. That matter is discrete was held by Greek philosophers, but unfortunately we have only scanty reference to them in quotations in writings of much later date. Naturally, the atomic theory when generally received led to speculations as to the possible unity of matter, that is, that all elements are but modifications of one form. In the middle of the nineteenth

century such speculation was quite popular; enthusiastic believers in it went so far as to give a name—protyle—to the primordial element. The exact determination of atomic weights showing many fractional numbers, the decimals of which could not be ascribed to errors of method, caused the abatement of the theory, which had been due mainly to Prout, and until the discovery of the remarkable transmutability of radio-active elements, chemists gave little thought either to the old alchemical visions of transmutation or to the hypothesis of an "Urstoff." Now the world has moved around to the old position on the staircase, but somewhat higher in level, and the isolation of isotopes has brought Prout's view more into consideration. After all, is not the evolution of matter as probable as the evolution of the objects which matter constitutes? The doctrine of the evolution of living forms is ancient, but the presentation of it with the evidence for its truth is due mostly to Darwin. His view on natural selection underwent a period of retrogression; it was considered good form to deprecate it, but at present naturalists seem to be returning to it.

Professor Lewis has given to chemists, physical chemists and physicists a valuable contribution, for he has summarized and vividly presented to most recent results and inferences in the field of atomic and molecular structure. Some of the older workers, and the more conservative, may, indeed, smile or even be irritated at the complication involved in the presentation of the structure of some simple molecules, but the evidence is at hand and the present-day teacher cannot afford to overlook these views. The book, as usual in the series to which it belongs, is well printed and up to date. HENRY LEFFMANN.

CHEMISCH-TECHNISCHE VORSCHRIFTEN. By Otto Lange, Technical High School, Munich. Third edition, enlarged and thoroughly revised, Vol. 2, Fasern, Massen und Schichten. xix–806 pages, 8vo. Leipzig, Otto Spamer, 1923. Price $8.35 net.

The general character of this work was set forth in a review of the first volume in the issue of this JOURNAL for September last. The work is to be in four volumes, and it is obvious, from the contents of the first two, that when completed it will be one of the most comprehensive and complete summaries of industrial chemistry in any language. The present volume deals with manufactured articles, mostly organic that are used in the form of fibers, sheets or masses of moderate size. Under the latter term—"Massen" in the original—are included leather, natural and artificial, bone, horn and sponge products, celluloid, adhesives, plastics, peat, sawdust, casein products, and many other more or less analogous materials. The section on fibers includes extensive treatment of paper, all forms of wood-fibers, artificial fibers, and the several forms of cellulose esters. Vegetable and animal fibers are, of course, extensively treated. In the section on sheets, sensitive films are described together with photographic processes, even the sources of light and the nature of light filters and screens are discussed. It is quite impossible in the space available to do more than indicate in outline the merits of this work. The amount of material collected is immense, and the copious references to patent and journalistic literature extend greatly the serviceability of the book. As stated in the review of the first volume, no narrow nationalism restricts Doctor Lange's view of chemistry. As in the first volume, the index references are

to paragraphs, not to pages, a method that at first embarrasses the American user, but this difficulty soon disappears. On the relative merits of page and paragraph reference much discussion might arise. The reviewer is strongly in favor of the former common and long-established method, but the other is not seriously objectionable. The index is very elaborate, and this is not the least commendable point in the book. The volume in hand sustains the position accorded to the first volume, and the work is undoubtedly one of the most valuable in the field to which it is devoted. The appearance of these extensive and excellent books must be considered evidence that along some lines, at least, Germany is rapidly recovering from the effects of the war.

HENRY LEFFMANN.

THE HANDBOOK OF INDUSTRIAL OIL ENGINEERING. By John Rome Battle, B.S. in M.E., M.E. Second edition, revised, 1141 pages, 100 line drawings, over 200 half-tones, 9 colored plates and many other illustrations, 9 charts, 8vo. Philadelphia, J. B. Lippincott Company, 1923. Price, $10, net.

The first edition of this book met a great want in engineering and was soon exhausted. The author has taken the opportunity to thoroughly revise and extend the work so as to bring it up to date. The mere enumeration of the subjects included would fill a large space. On account of this comprehensiveness, the book will find application in all the fields of oil engineering and be a valuable reference work for all persons associated with the manifold uses in which oil is now employed. The volume in hand is, indeed, only one portion of the work, being the section devoted to lubricating and industrial oils.

The enormous number of illustrations constitute in themselves a vivid picture of the importance and extent of the use of oils. Over a hundred useful tables are included. It is a reference book of data, relating to lubrication and industrial oils, including tables, general oil information, engineering and industrial requirements, for the use of oil engineers, lubricating engineers, oil salesmen, oil equipment manufacturers, mechanical engineers, machinery designers, mill and power plant superintendents, and others interested in the efficient utilization of oil products and equipment, and the conservation of power.

The mechanical construction of the book is excellent, and a comprehensive index will greatly aid the user. HENRY LEFFMANN.

MANIPULATIONS DE CHIMIE COLLOIDALE. Par Wo. Ostwald. Translated by Edmond Vellinger, with permission of the author. 201 pages, 21 illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1924. Price, 10 Francs.

This being a translation from a standard work, that has already gone through four editions in its original language, requires little more than the announcement of publication. The book contains a large number of directions for obtaining colloids and demonstrating their properties. The part played by chemistry in many sciences is widening steadily, and chemical principles and methods find application in many ways, especially in physiology, biology and medicine. New methods must be employed with a knowledge of the mechanisms involved, as far as these can be ascertained. The translator has done good service to French chemists by rendering this book into their language. Beginners in the study of colloid chemistry will find it of great value. The translation carries the first and fourth prefaces of the German work. In the latter,

the author states that some reviewers have suggested that an index should be added, but he has deliberately declined, inasmuch as the table of contents is elaborate and will answer all purposes. This attitude is to be regretted. As might be expected, with this example before him, the translator has not supplied an index. HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Chemisch-Technische Vorschriften. Ein Handbuch der speziellen chemischen Technologie von Dr. Otto Lange. Dritte, erweiterte und völlig neubearbeitete auflage. II Band, Fasern, Massen und Schichten. 806 pages, 8vo. Leipzig, Otto Spamer, 1923. Price, in paper, $8.35.

Technical Methods in Analysis of Metallurgical and Allied Products. A manual of analytical methods and useful data for the chemist and the college student by Wilfred W. Scott. 875 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1923. Price, $6.

Valence and the Structure of Atoms and Molecules. By Gilbert Newton Lewis. American Chemical Society Monograph Series. 172 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1923. Price, $3.

The Handbook of Industrial Oil Engineering. A reference book of data, relating to lubrication and industrial oils, including tables, general oil information, engineering and industrial requirements, for the use of oil engineers, oil salesmen, oil equipment manufacturers, mechanical engineers, machinery designers, mill and power plant superintendents, and others interested in the efficient utilization of oil products and equipment, and the conservation of power, includes the lubricating engineer's handbook revised by John Rome Battle. Second edition, revised. 1141 pages, illustrations, diagrams, plates, maps, 12mo. Philadelphia, J. B. Lippincott Company, 1923. Price, $10.

A Treatise on Engine Balance Using Exponentials. By P. Cormac. 151 pages, illustrations, 8vo. New York, E. P. Dutton and Company, 1923. Price, $8.

Textile Chemistry. An introduction to the chemistry of the cotton industry by F. J. Cooper. 235 pages, illustrations, 8vo. New York, E. P. Dutton and Company. Price, $5.

Cours Complet de Mathématique Spéciales. Par J. Haag. Tome IV, géométrie descriptive et trigonométrie. 152 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1923. Price, 13 Francs.

Exercices du Cours de Mathématique Spéciales. Par J. Haag. Tome IV, géométrie descriptive et trigonométrie. 154 pages, 8vo. Paris, Gauthier-Villars et Cie., 1924. Price, 15 Francs.

L'Industrie du Gaz. Traitement des Produits et Sous-produits. Par René Masse et Auguste Baril. Encyclopédie Léauté. 307 pages, illustrations, 12mo. Paris, Gauthier-Villars et Cie., 1923. Price, 20 Francs.

L'Industrie du Gaz. Distillation de la Houille. Par René Masse et Auguste Baril. Encyclopédie Léauté. 295 pages, illustrations, 12mo. Paris, Gauthier-Villars et Cie., 1923. Price, 20 Francs.

La Lumière Monochromatique, sa Production et son Emploi en optique pratique. Par Ch. Fabry. 37 pages, illustrations, 8vo. Paris, Revue d'Optique theorique et instrumentale, 1923.

Les Applications des Interférences Lumineuses. Par Ch. Fabry, professeur a la Sorbonne. 160 pages, illustrations, 8vo. Paris, Revue d'Optique theorique et instrumentale, 1923.

Ventilation of Central Station Buildings and Equipment. A report of the sub-committee on ventilation of the Electrical Apparatus Committee. 46 pages, illustrations, quarto. New York, National Electric Light Association, 1923. Price, 40 cents.

Ontario Department of Mines. Thirty-first Annual Report, 1922. Two parts, illustrations, maps, 8vo. Toronto, King's Printer, 1923.

National Advisory Committee for Aeronautics. Technical Notes, No. 161, Preliminary Study of the Damping Factor in Roll, by Lieut. James M. Shoemaker, U. S. N. 17 pages, diagrams, quarto. No. 162, The Arithmetic of Distribution in Multi-cylinder Engines, by Stanwood W. Sparrow. 9 pages, diagrams, quarto. No. 164, General Theory of Windmills, by Max M. Munk. 5 pages, diagrams, quarto. No. 165, Tests on Riveted Joints in Sheet Duralmin, by H. F. Rettew and G. Thumin. Abstracted and revised by J. G. Lee. 5 pages, diagrams, quarto. Washington, Committee, 1923.

List of Manuscript Bibliographies in the Biological Sciences.—This treatise has been compiled by CLARENCE J. WEST and CALLIE HULL, and published as No. 45 in the Reprint and Circular Series of the National Research Council (Washington, D. C., June, 1923, 51 pages). It includes unpublished bibliographies in the biological sciences which are available to research workers. Separate sections are devoted to biochemistry and biophysics. Many bibliographies of a distinctly chemical nature occur in other sections, such as those devoted to physiology and pharmacology. The following information is given for each bibliography: Compiler and his address, number of entries, years covered, other items of interest. Many entries in the list, such as those devoted to canned foods, insecticides, fertilizers, photosynthesis, meteorology, are of deep interest to the technologist.

J. S. H.

Identification of Amines.—C. S. MARVEL and F. E. SMITH, of the University of Illinois (*J. Am. Chem. Soc.*, 1923, **45**, 2696–2698), recommended para bromobenzenesulphonyl chloride as a reagent for the identification of amines. This reagent is treated with a slight excess of the amine. If necessary, heat is applied to start the reaction. The resulting para bromobenzenesulphonamide is purified by washing with dilute hydrochloric acid, and recrystallization from alcohol of the proper concentration, and is then identified by its properties, such as its melting point and the percentage of bromine found on analysis.

J. S. H.

CURRENT TOPICS.

Platinum Conditions in 1922.—Advance sheets of the 1922 issue of the "Mineral Resources of the United States" have just been distributed by the Geological Survey. The section devoted to platinum and allied metals was prepared by J. M. Hill. The enormous advance in the price of platinum has been a serious burden upon some industries and upon chemists. The metal is practically indispensable in a few analytic operations, though fused quartz and some alloys have partly relieved the strain. For many years, manufactured platinum ware sold at retail at about three cents a grain. Crude metal in ingots was sometimes as low as $9 per troy ounce. The principal supply was from the Urals, only small amounts coming from other sources, some South American gold occasionally yielding a little. The price began to advance about the beginning of the present century, and with slight fluctuations has steadily increased until platinum wire was lately quoted by a supply house at $3.97 per gram, close to $125 per troy ounce, about six times the price of gold. As soon as the price advanced materially above that of gold, jewelers began to use it, and the consumption for this purpose has contributed largely to the present exalted figure. Nearly 70 per cent. of the platinum used in the United States enters into jewelry.

The report gives no encouragement to those who are hoping for a material reduction in cost of the metal. Notwithstanding the intensive search, stimulated by the high price, no new localities of importance have been found. A promoter's boom was started in one of the western states, but soon collapsed under expert examination. The Russian field has not yet resumed active supply. In 1913, 250,000 troy ounces were furnished by it. The yield fell to one-half in 1915, and steadily decreased, until in 1921 only 20,000 ounces are credited. Colombia is now the most abundant producer, nearly 40,000 ounces having been imported into the United States in 1922. This is, of course, crude, carrying more or less of the related metals. The production in the United States is inconsiderable; only about 1000 ounces in 1922. A notable item is the use of palladium in jewelry for the manufacture of the so-called "white gold." The price of this metal has remained during the year at about $55 per troy ounce. Iridium has risen greatly, closing for the year at $260 per troy ounce. The customs reports for the year show no direct Russian supply, but considerable importations from Asthonia, Latvia and Sweden are believed to be of Russian origin. About 35,000 ounces credited to England and 11,400 to France are, of course, obtained from other countries, probably principally from Colombia and Russia. No definite information, however, seems to be at hand as to the extent to

which the Russian fields were worked during the period covered by the report.

The relative amounts of platinum and allied metals used in certain industries are approximately as follows:

	Per cent.
Jewelry	66.6
Electric apparatus	16.1
Dental materials	9.5
Chemical apparatus	5.2

The balance is distributed through several minor industries. The most marked increase over 1921 is in jewelry, which rose from 59.5 per cent. to the figure given above. H. L.

Notes from the Sixty-sixth Meeting of the American Chemical Society, Held at Milwaukee, Wisconsin, September, 1923.—*Furfural from Corn-cobs.*—Further investigation of the properties of furfural, obtained from corn-cobs, has indicated, according to the paper by Mahood and Harris, that a rich brown dye can be made from this substance. The experiments of these authors may lead to the production of an entire series of dyes in which this material is used to replace others already in use and thus in a series of dyes entirely American both as to method and materials of manufacture.

Natural Water Corrosion of Steel in Contact with Copper.—Experiments are described by Whitman and Russell wherein the natural water corrosion of steel in contact with a metal lower in the electromotive series has been quantitatively determined. The results show that the total corrosion is the same with bare steel plates as with steel specimens of the same size having 75 per cent. of their surface copper plated, *i.e.*, in the latter case the corrosion per unit area of steel is four times as great as in the former. The total corrosion observed is determined by the total effective surface available for the depolarization of hydrogen by dissolved oxygen, the actual corrosion occurring on the steel alone.

These results are not readily explainable by the colloidal theories of corrosion advanced by J. N. Fried or Bengough and Stuart, both of which agree that hydrogen is not an essential in natural water corrosion. The data are, however, in entire accord with an electrolytic mechanism of corrosion. The electrolytic theory explains these results by picturing the increased corrosion per unit area of steel as caused by the depolarization of a film of nascent hydrogen. This film is deposited on the steel and on the adjacent copper surface and its removal is affected by diffusion of dissolved oxygen into the metal. The rate of corrosion is limited by the rate at which oxygen can diffuse in to react with the surface film of nascent hydrogen.

The Rôle of Bread in Nutrition.—Worth Hale finds that the consumption of wheat products in the United States rose, in the years 1915 to 1920, from 5.3 bushels to 5.8 bushels per capita. Bread is the

chief nutrient eaten at one or more meals each day by many growing children. The nutritive quality of bread thus becomes an important factor in the growth and health of these children and, to a less extent, the health of adults.

Only one commercial white bread and no whole wheat bread, of many examined, was found to be adequate for the growth and maintenance of animals. Experimental white breads, made with the addition of the aqueous extract of wheat embryo and with a small percentage of milk, proved far superior to the average white or whole wheat bread. A commercial white bread, developed along similar lines, likewise is far superior to all breads examined, including so-called cream, vitamin, and whole wheat breads. This bread equals the growth inducing qualities of normal diets and protects animals from the development of xerophthalmia and polyneuritis. Its high value as a nutrient is further supported by children feeding tests.

H. L.

The Movement of Water in a Body Caused by Explosions in the Liquid. C. RAMSAUER. (*Ann. d. Physik.*, 1923, No. 20.)—When a charge is set off under water, a spherical wave of pressure travels outward with a speed dependent on the compressibility of water. At the same time the gases developed by the explosion push the adjacent water bodily outward. It is with this second phase of the phenomenon that the present investigation concerns itself.

The apparatus for detecting the bodily motion of the water consists of an electric circuit containing a battery, an electromagnet and connecting wires. When the circuit is closed, the electromagnet attracts its armature in opposition to the pull of a spring. The cessation of the current is followed by the release of the armature. In use the electromagnet and battery are set up on land at a safe distance, but the connecting wires, properly insulated, pass through the water to the vicinity of the explosion. There the wire is no longer continuous. It is cut and the two ends are both in the water. Sufficient current flows from one end to the other to hold the armature in place. One end of the wire, that placed nearer to the centre of explosion, is in reality merely an end of wire, while the other is expanded into a plate.

When the charge is set off, the retention of the armature indicates that water has remained between the wire and the plate. On the other hand, the release of the armature shows that the expanding gas has thrust away the water from the wire and has thus interrupted the electric circuit. A series of such pieces of apparatus, set at different distances from the explosion, will furnish information in regard to the distance through which the water is bodily pushed away by the explosion. If one armature is set free, while an adjacent one is held in position, it follows that the expanding gas reached one terminal wire but did not go far enough to reach the neighboring wire.

In the experiments the two variables introduced were the number

of grams of guncotton used and the depth of the cartridge below the surface of the water. The greatest distance outward through which the water was projected was found to be closely in proportion to the cube root of the mass of the charge divided by the pressure at the point of explosion. With the same charge of 1910 grams the water was moved outward through 166 centimetres, when the cartridge was situated three metres below the water surface, and 146 centimetres, when the depth was eight metres. Reducing the charge to 470 grams caused the distance to come down to 98 centimetres.

The same apparatus was used to measure the speed of motion of the out-thrust water. The interval between the interruption of two circuits whose wires were at different distances from the centre of explosion was recorded. The speed, as would be expected, diminished with the distance from the cartridge. At a distance of 40 centimetres it was 63 metres per second, but only 12.5 metres per second at three times the distance from the source. G. F. S.

Coal in 1919, 1920 and 1921.—A pamphlet of 218 pages, covering pages 445 to 662 of the forthcoming volume of the report on "Mineral Resources of the United States," has just been issued under the auspices of the U. S. Geological Survey. The section has been prepared by F. G. Tyron and S. A. Hale. The United States is the greatest coal-producing and coal-consuming country in the world, and notwithstanding the extent to which its supplies have been drawn on, enormous quantities still remain and early exhaustion is not probable. The coal-mining industry has of late been subject to great interference through strikes, and disagreements between operators and workers. The work is hard and dangerous. Injuries, fatal and non-fatal, are common, and every now and then the nation is shocked by some wholesale disaster. Several types of coal are found in the country. The anthracite deposits of Pennsylvania are practically unique and constitute the best fuel for domestic use. It is, however, steadily increasing in price, although some of the smallest sizes, which are by-products of preparation for market, are in excess of demand, largely on account of the lack of furnaces suitable for use of them.

The report which suggests this note gives elaborate statistics of the production and handling of coal produced in the United States during the years 1919, 1920 and 1921, and a chart, prepared by Miss Lida Mann, shows the amounts of coal produced each year since 1807. The figures for the years 1807 to 1820 are combined. In this first period 15,000 tons were mined, of which 300 were Maryland bituminous and the rest Pennsylvania anthracite. The high-water mark for anthracite was in 1917, when nearly 100,000,000 tons were mined. The total production of anthracite to date is over 3,000,000,000 tons, and of all forms of coal over 14,000,000,000. The number of men employed in anthracite mining has fallen off somewhat; in the last year covered by the report, it was nearly 160,000. A much larger

number work in the bituminous mines, the figure for 1921 being over 660,000. The working days do not reach quite 300 for each year, the deficiencies being due to Sundays, legal holidays and certain national or religious holidays of groups of workers. Statistics of injuries in the mines are not included as these matters belong to another department.

In this connection may be mentioned a paper in the *Trans. and Proc. of the Royal Society of South Australia* (1922, **44**, 131), by Sir D. Mawson and F. Chapman, on the brown coals of that region. Analysis shows the following average composition: Loss at 105° C., 51 per cent.; volatile matter, 21 to 25 per cent.; fixed carbon, 13 to 15 per cent.; ash, 9 to 13 per cent. The nature of the volatile matter is not given, but it is probably of considerable volume and low illuminating power. H. L.

The Effect of Torsion on the Thermal and Electrical Conductivities of Metals. C. H. LEES and J. E. CALTHROP. (*Proc. Phys. Soc.*, Aug. 15, 1923.)—"The close connection which all forms of the electron theory of flow of heat and electricity in metals disclose between the conductivities k for heat and K for electricity make it desirable that these quantities should be determined for as many metals and under as many different conditions as possible in order to see the extent to which the theories agree with the facts."

It is easy to measure with accuracy the electrical resistance of a wire whether twisted or free from torsion. Immensely more difficult is it to determine the difference between the thermal conductivities of the same wire in the strained and in the unstrained state. The following method was used: The wire was stretched between two clamps in a space surrounded by a water jacket. Around the middle of the wire was wound a heating coil. When current flowed through this, the temperature fell from the coil in both directions toward the clamps at the ends. Two platinum thermometers are attached to the wire so as to give the temperatures at two points on the same half of the wire. The water jacket maintained the ends of the wire at a constant temperature. With the heating coil in action the thermometer near to it showed a higher temperature than the one near to the clamp. Upon twisting the wire, a redistribution of temperatures was brought about owing to a change in conductivity for heat, and the thermometers indicated different temperatures. The two thermometers in one case with the wire not twisted showed a difference of .24° C., and with the wire twisted a difference of .94°. From the readings of the thermometers the thermal conductivity of the wire was calculated by the use of an equation containing hyperbolical functions. It was found that both the electrical and the thermal conductivities grow less with torsion. The rate of change is considerably less for the electrical coefficient than for the thermal. In both cases the change is approximately in proportion to the twist per unit length. G. F. S.

Test for Olive Oil.—W. H. DICKHART, of the New York Produce Exchange (*Am. J. Pharm.*, 1923, **105**, 684–686), has devised the following test for olive oil. Two reagents are used, (1) a mixture of one part of concentrated sulphuric acid and four parts of absolute alcohol, and (2) a 5 per cent. solution of furfurol in alcohol. A 5 c.c. sample of the oil is shaken in a test tube with 5 c.c. of the alcoholic sulphuric acid to form an emulsion; then ten drops of the alcoholic furfurol are added and incorporated into the emulsion by shaking. A pink color at this stage indicates the presence of sesame oil, which interferes with this test for olive oil, and, therefore, renders further procedure useless. In the absence of sesame oil, the tube and its contents are kept in a bath of hot water at a temperature of 94° to 95° C. for ninety seconds, shaking every few seconds. The tube is now removed from the bath; 10 c.c. of cold water are added to its contents, and mixed by shaking. The tube and its contents are then permitted to stand for ten minutes. A red colored solution indicates the presence of olive oil. The other oils tested (refined cottonseed, corn, castor, chinawood, hempseed, kapok, peanut, perilla, palm, palm kernel, lumbang, mustard, rapeseed, teaseed, linseed, soy bean, cocoanut, and tobacco seed oils) yielded only a milky solution. Certain of these oils give a color prior to the addition of the water; thus a slight red is given by palm kernel, peanut, cocoanut, teaseed, and castor oils, and a greenish blue by mustard oil; however, these colors vanish and are replaced by a milky solution upon the addition of water. This test will show the presence of 2 per cent. of olive oil in another oil. If oil of rosemary be present in excess in olive oil, the volume of water added in the test should be increased to 15 c.c.; the solution becomes a dark red approaching a chocolate color, while the oil also is much darker than usual. J. S. H.

Tin as a Catalyst.—According to O. W. BROWN and C. O. HENKE, of Indiana University (*J. Phys. Chem.*, 1923, **27**, 739–760), metallic tin may act as a catalyst in the reduction of nitrobenzene to aniline by hydrogen, also in the reduction of ortho nitrotoluene and ortho nitroanisole to ortho toluidine and ortho anisidine, respectively. The tin acts better in coarse lumps than in the powdered form. Catalysis occurs at a lower temperature in an iron vessel than in one of glass. In some experiments, from 93 to 99 per cent. of the theoretic yield was obtained. J. S. H.

Automobiles in Australia. (*Machinery*, Oct., 1923.)—Australia is to-day, as it has been for some time past, the leading export market for American automobiles. The value of the cars exported to Australia in 1922 was $23,000,000. In addition, considerable exports were made from Canada by American manufacturers having Canadian branches. Forty per cent. of the entire exports of the country were represented by eight of the best known makes of American cars.

Tin Production in 1922.—Tin, though classed among the "base" metals, has some analogies to platinum. Its high luster, practical permanence in the air and resistance at ordinary temperature to some common corrosive agents have made it of great use in the household and in some industries. Like platinum, the supply is much below the world's needs, only a few rich deposits being known. The Cornwall mines worked for centuries, are still yielding metal. Hopes were entertained some years ago that tin might be found in quantity in the United States, but these have not been realized. In 1916, 140 tons of metallic tin were produced, but the yield has steadily fallen, until in 1922 only 1.4 short tons, all from Alaska, were reported. The tin industries in this country rely, therefore, upon imports. The largest sources for 1922 were, for metal, England 10,000 tons and Straits Settlements 47,000. Tin concentrates were imported to the amount of 12,507 tons from Chile, but as Bolivia has no ports, the material was probably from the Bolivian mines, which are among the world's important sources. The data given in this note are taken from a compilation by B. L. Johnson, being part of the report on the "Mineral Resources of the United States" for 1922, issued in form of advance sheets by the U. S. Geological Survey. H. L.

The Diminished Intensity of the Red Part of the Solar Spectrum Observed in Equatorial Regions. L. GORCZINSKI. (*Comptes Rendus*, Oct. 22, 1923.)—On a journey to Siam and Java about 40,000 observations of the radiation received from the sun were made. Though all these have not been worked over, the author "indicates an important point that emerges from the mass of observations, to wit, the progressive diminution in the intensity of the red part of the solar radiation that shows itself on a voyage from Europe to the equator." The measurements show a difference of about 10 per cent., that is, under the equator 45 per cent. of all solar radiation is in the red, while in Europe 50 per cent. is in that part of the spectrum. "It is to the difference in distribution of solar energy throughout the spectrum that we must attribute the characteristic effects of sunlight in the tropics. The deficiency in the red part of the spectrum, joined to the excess in the violet, can alone explain the peculiarities of animal and vegetable life in the tropics." His results justify the author in suggesting the great desirability of studying the energy distribution in the spectrum for different regions of the earth. Of particular value would be observations made in desert regions, upon mountains, under the equator and on an island such as Tahiti. G. F. S.

On a Coil Galvanometer of Rapid Indication. W. J. H. MOLL. (*Proc. Phys. Soc.*, Aug. 15, 1923.)—The properties of more rapid indication and greater stability have been attained by modifications in design. The moment of inertia is made small by the use of a coil whose vertical length is great in comparison with its horizontal width. This reduces the period of swing. "Now when the moment of

inertia of the coil is made very small, and its weight consequently very slight, it will suffer from inevitable vibrations to a much higher degree than would be the case with a heavier coil. The desired stability has been obtained in a rather obvious way, namely, by simply stretching the coil between two metal wires, instead of suspending it." A photographically registered series of deflections shows that the instrument is very dead-beat. About two seconds were required for the deflections to reach their maximum value. This once attained, the record is free from any trace of a tendency in the coil to swing back toward its zero position. G. F. S.

Water-cell Transmissions and Planetary Temperatures. D. H. MENZEL. (*Astrophys. J.*, Sept., 1923.)—The radiation reaching the earth from a planet is the sum of two parts. One of these consists of waves of short length, originating at the sun and reflected by the planet. The other is the long wave radiation emitted by the planet itself. A water cell transmits the first part but stops the second entirely. The water-cell transmission is the ratio of the energy from the planet that emerges from the receiving instruments when a water cell is in its path to that which comes through without the cell. A formula is developed that connects the transmission with the temperature of the planet. This is possible because the energy radiated by the planet is dependent on its temperature.

Of the members of the solar system observed Jupiter has the largest water-cell transmission, about .67, while the moon has the smallest, .147. These temperatures are deduced—Venus, 50° C.; Mars, −16° C.; Jupiter and Saturn, −110° C., "while the moon is very hot, possibly 120° C. . . . The computed temperatures of Venus and Mars can be explained if they receive all their heat from the sun and lose it almost as fast as they receive it, cooling greatly at night. Jupiter and Saturn have higher temperatures than could be maintained by solar radiation alone, confirming the belief that the planets are hot internally." G. F. S.

Is the Sun Responsible for the Radioactive Products of Disintegration in the Atmosphere? H. BONGARDS. (*Physikal. Z.*, July 15, 1923.)—In the air there are found products of the transformation of radioactive substances. It is no easy matter to determine by a crucial test whether these owe their origin to the earth or to bodies outside of the earth. Observations at high altitudes would be decisive only if the elevations were so great as to preclude any considerable terrestrial influence. Another way of testing would be to make observations all over the earth of the amount of emanation in the air and to extend these observations over a considerable period of time. Were the fluctuations of the quantity of emanation to follow the same course at all stations, this would argue for an extra-terrestrial cause.

The author discovered that observations made by Wright and Smith in the Philippines at Manila overlapped in time a series made by himself in Germany. He has plotted the curves showing how the quantity of emanation varied during three months. The similarity of the curves is remarkable. This by no means proves that the sun or some other distant body controls the emanation content of our atmosphere, but it does indicate that the method of simultaneous observation is well worthy of trial. G. F. S.

The Constitution of the Upper Strata of the Atmosphere. L. VEGARD. (*Phil. Mag.*, Oct., 1923.)—A generation ago the discovery of argon in the air unsettled the view then in vogue that all was known about the atmosphere. In the physics of the atmosphere there followed the establishment of the isothermal layer and a lengthy discussion of the escape of molecules of gases from the outermost strata. There came a time when the opinion prevailed that the highest regions contained hydrogen and helium, while nitrogen and oxygen were confined to relatively low levels. In a recent lecture before the Royal Meteorological Society, G. M. B. Dobson said: "Since the beginning of the present century, exploration by means of kites and balloons has increased our knowledge so rapidly that it may be said that we now know the general characteristics of the atmosphere up to about 20 km. with very fair accuracy. Above 20 km., however, our information practically ceases, and there seems, at present, very little hope of getting any direct observations above, say, 25 or 30 km. To obtain further information about the atmosphere above these heights, one must, therefore, look around for more or less indirect methods. There are various phenomena which occur at these altitudes which might conceivably indicate the conditions of the atmosphere, such as auroræ, meteors, night-luminous clouds, etc." Lindemann has published the results of his study of the appearance and disappearance of meteors. Lord Rayleigh is photographing the spectra of the aurora at different latitudes in England, but it is to physicists nearer to the pole that we must look for observations that will be the raw material for the elaboration of the final and satisfactory theory of the upper regions of the atmosphere. Already in the year 1923 Stormer and Vegard have made important contributions to the subject. In this, his latest paper, Vegard states that last winter he succeeded in getting spectrograms of auroræ at different altitudes. "In the first paper we saw that most of the lines appearing in the auroral spectrum are due to nitrogen, but the strongest of all lines (the green line) and three faint lines in the blue and the ultra-violet could not be found among the lines of nitrogen observed in laboratory experiments and given in tables of spectral lines. Nor can they be found among the known lines of hydrogen and helium. Already this result suggests that the green line and the other three not identified lines are due to nitrogen." Needless to say, the question cannot be resolved by a mere suggestion. Last March the author got a spectrogram of the lower edge of an

aurora with an exposure of half an hour and another of the higher parts of the same auroral display with an exposure of four hours. "The most remarkable result is, that the intensity of the green line as compared with that of the strong negative N-bands is quite as great near the bottom edge as it is 50–80 km. higher up in the atmosphere." This weighs heavily in favor of attributing the origin of the famous green line to nitrogen. If some other elementary gas gave rise to the line, this suppositional gas would have a density different from nitrogen and the relative proportions of it and nitrogen would not be the same through a height of 50–80 km. This change in the composition of the atmosphere would show itself in a difference between the two spectrograms, or, more specifically, in a variation in the relative strengths of the green line and of the unquestionable nitrogen bands.

The argument just used does not, however, rule out the possibility that some compound of nitrogen might emit the green line. Such a compound would of necessity have about the same molecular weight as nitrogen or, at most, not a greater molecular weight so that it might exist along with nitrogen in the upper atmosphere. NH_3 alone is worth consideration and the evidence of the spectrograms rules it out. "I think that the 'Geocoronium' hypothesis ought to disappear from the scientific literature, and if so the only possible interpretation of our auroral spectral analysis is to assume that also the green line is a nitrogen line emitted under those peculiar physical conditions under which the light is produced in the upper strata of the atmosphere."

The spectra of the aurora up to 400 km., or even higher, proves that nitrogen is "a predominant component of the atmosphere to its very extreme upper limit." To explain how there can be sufficient nitrogen at such great altitudes to give rise to the spectra actually observed one of these two hypotheses may be held—

(*a*) "We might either assume that above a certain height the temperature increased rapidly upwards," or

(*b*) "That the nitrogen was electrically charged by photo-electric effect and driven upwards through the effect of the electric field produced by the charged layer."

Turning to the first of these alternatives, Vegard sees that a temperature of several hundred degrees in the upper atmospheric strata would account for the relatively great density of nitrogen required in the regions of the aurora. He is compelled to reject this alternative on experimental evidence. He bombarded nitrogen at room temperature and again at the temperature of liquid air with cathode rays and found that at the higher of these two temperatures the spectrum of the gas was much more complex than is that of the aurora, while there was great similarity between the lines of the auroral spectrum and those of nitrogen at the lower temperature. "If now we have to give up the assumption of a high temperature, I can see no escape from the assumption that nitrogen in some way or other must be driven upwards through the effect of electrical forces." Such forces

are furnished by the negative charge of the earth and the positive charge above its surface. "At a certain height the positive electric mass just equals the negative, and on a sphere at this distance the electric force will be zero. Under this niveau the electric force is directed downwards, and only above it will there be an upwardly directed electric force." Somehow in the outer layers of the atmosphere electrons are removed from the nitrogen atoms, which are then left with a positive charge. The electric field of the earth urges them outward and to avoid the constant depletion of our atmosphere by a flow of nitrogen out into space the author predicates the existence of the nitrogen in the form of solid crystals. Nitrogen freezes at about 60° absolute. "But if these are the conditions under which the auroral spectrum is formed, we can understand why a nitrogen spectrum like that given out by the auroræ has never been reproduced in laboratories, for we should then have to bombard solid nitrogen dust with electric rays. . . . At present I am making preparations for experiments of this kind." How interesting it will be, if the green line is produced in these experiments!

We are then to regard this as the composition of the atmosphere—up to about 90 km. from the earth oxygen and nitrogen gases, above that dust of the two solidified elements.

The claim is made that this theory furnishes an explanation of the zodiacal light, of the blue color of the sky, of the twinkling of fixed stars and the absence of twinkling in planets, of the reflexion of electric waves and sound waves from the upper layer of the atmosphere, of the sudden change of color along a meteor track and of the increase of the maximum height of auroral rays as the equator is approached. G. F. S.

Colorimetric Standards.—H. V. ARNY and ABRAHAM TAUB (*J. Am. Pharm. Asso.*, 1923, **12**, 839–849) state that the colors produced in colorimetric determinations can usually be matched by use of two sets of solutions, each of which includes three compounds representing the three primary colors. One set is composed of half-normal solutions of cobaltous chloride, ferric chloride, and cupric sulphate, respectively, in approximately 1 per cent. hydrochloric acid. The other set consists of fiftieth-normal solutions of roseo-cobaltic chloride, ammonium chromate, and cupric sulphate, respectively, in 2.8 per cent. ammonia water. These solutions may be used as standards in the colorimetric determination of carbonizable impurities in liquid petrolatum, and in the assay of suprarenal glands for their epinephrine content. J. S. H.

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